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ABSTRACT

The Forestry/Natural Resources Sector in the Office of Training and Program Support of the Peace Corps conducted an agroforestry inservice training workshop in Honiara, Solomon Islands, in 1983. Participants included Peace Corps volunteers and their host country national counterparts from six countries of the Pacific Islands and Asia (Western Samoa, Fiji, Papua New Guinea, Philippines, Thailand, and the Solomon Islands). The workshop design combined technical presentations with appropriate hands-on experiential learning sessions. One of the principal goals of the workshop was to train teams of Peace Corps volunteers and host country counterparts in the concepts of agroforestry while at the same time strengthening their personal relationship. Emphasis also was placed on broadening the participants' knowledge of different extension techniques and strategies and providing them with an opportunity to practice those techniques. The workshop also stressed the role of women in development, especially in forestry. The actual sessions on agroforestry focused on the ecological, economic, social and technical aspects. They included an historical overview; advantages and disadvantages; tree, crop, and animal production within a system; nitrogen fixing trees; project planning; seed selection and storage; and fruit tree preparation and management. (This document contains outlines of the training sessions as well as technical information on agroforestry.) (KC)

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Peace Corps

AGROFORESTRY IN-SERVICE TRAINING

HONIARA, SOLOMON ISLANDS, SOUTH PACIFIC
OCTOBER 23, - OCTOBER 29, 1983

A Training Aid

For

ASIA & THE PACIFIC ISLANDS

Prepared by
Jacob Fillion & Julius Weeks

FORESTRY/NATURAL RESOURCES SECTOR
OFFICE OF TRAINING & PROGRAM SUPPORT
PEACE CORPS
WASHINGTON, D.C. 20526

MAY 1984

EXECUTIVE SUMMARY

The Forestry/Natural Resources Sector in the Office of Training & Program Support of Peace Corps conducted an Agroforestry In-service Training Workshop in Honiara, Solomon Islands, from October 23 - 29, 1983. Participants included Peace Corps Volunteers (PCV) and their Host Country National Counterparts (HCN) from six countries of the Pacific Islands and Asia. Those countries represented included Western Samoa, Fiji, Papau New Guinea, Philippines, Thailand and the Solomon Islands. Of the 33 participants in the workshop, 21 were Peace Corps Volunteers and 12 were Host Country National Counterparts who in most cases work directly with the Peace Corps Volunteers on their project/program.

The workshop design combined both technical presentations with appropriate "hands-on" experiential learning sessions. It was designed to meet the needs of the participants as expressed through cable traffic and data collected during a pre-research trip to the Solomon Islands in June.

One of the principal goals of the workshop was to simultaneously train counterpart teams of PCVs and HCNs in the concepts of agroforestry while at the same time strengthening their personal working relationship.

Emphasis was also placed on broadening the participants' knowledge of different extension techniques and strategies and to provide them with an opportunity to practice these techniques. As important components of the extension strategy, site survey and information gathering skills, activities of great importance to the extentionist, were discussed and improved through hands-on activities.

We also stressed the role of women in development, more specifically women in forestry, and the importance of integrating women into the entire process of project planning and implementation for a holistic approach to human resource utilization and development.

The actual sessions on agroforestry focused on the ecological, economic, social and technical aspects. They included an historical overview; advantages and disadvantages; tree, crop and animal production within a system; nitrogen fixing trees; project planning; seed selection and storage; fruit tree preparation and management.

The goals of the workshop were met to the satisfaction of the workshop staff. Most importantly, the unique opportunity of training both Peace Corps Volunteers along with their respective Host Country National Counterparts proved very effective and beneficial in strengthening and building a more confident working relationship between them. In addition, each participant, as part of a group, prepared an oral presentation related to their field trip experience in which they utilized their extension and survey methodology skills. This experience along with the other sessions provided them practical "hands-on" experience hopefully giving them more confidence in recommending and incorporating, where appropriate, traditional or new systems of agroforestry in accordance with the local needs and conditions of their work sites.

ACKNOWLEDGEMENTS

The Forestry/Natural Resources Sector in the Office of Training & Program Support of Peace Corps would like to express its gratitude to everyone who assisted in the Solomon Island Agroforestry In-service Training workshop. The following people deserve a special note of thanks for their contribution and support: Harold Senter and Ian Knight who lead training sessions and donated numerous hours to the workshop without any financial compensation; to Graham Richardson and the staff of the Solomon Island Broadcast Corporation where the workshop was held; to the staff of Peace Corps Solomon Islands, including Carolyn Siota, Administrative Officer, Carol Kimball, Peace Corps Fellow/Acting APCD, Joanne Russa, Peace Corps Cashier, Yvonne Holt, Peace Corps Nurse and most importantly, Richard Mullaney, Acting Peace Corps Director; to the Manager and staff of the Hotel Mendana where the participants resided while in the Solomon Islands; to Kara Teati, Chief Field Officer of the Solomon Islands Agricultural Extension Service; Barnabas Likiopu, Extension Officer; Stephen Colbert of the Solomon Islands Development Bank for material support rendered.

Any workshop requires a great deal of planning. Bruce Burwell and John Schenk were of particular help during the pre-research and planning phase of the training program as well as in rendering continual assistance during the workshop and facilitating many of the training sessions. To Bruce and John a special thanks from the staff at Peace Corps/Washington.

We would also like to acknowledge the cooperation of former Peace Corps Director/Solomon Islands Frank Juska. Through his initiative and enthusiasm, the Solomon Islands was chosen as the site for this In-service Training.

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FOREWORD

Through the joint PC/AID Collaborative Forest Resource Management Initiative (PASA), Peace Corps has been able to design and pilot technical natural resource in-service training workshops (IST) for each of the three regions. These workshops have been designed to provide technical training for both PCVs and their Host Country National Counterparts. Through these pilot in service trainings, training aids have been developed to be used by the countries in the respective regions to assist in the design and implementation of their own natural resource ISTs. The Solomon Islands Agroforestry IST was the fourth completed under this PC/AID joint effort.

The proceedings of the Solomon Islands' IST have been compiled as a training aid for the NANEAP Region. The sessions included here may be used as guidelines when planning future ISTs and modified as needed to fit each country's specific requirements. You may find that particular sessions are not appropriate to the needs of certain countries and may/should be deleted or you may wish to add other topics not covered here. Whatever the case, we hope that this material will be of assistance to you and facilitate the designing of future agroforestry in-service training workshops.

COMMENTS AND RECOMMENDATIONS

This segment of the report is devoted to guidelines we feel are absolutely indispensible to careful, proper planning and implementation of ISTs. The following are a few comments and recommendations that may be of assistance when planning future agroforestry workshops.

- When conducting "needs assessment" and pre-research for an IST similar to this one, it is very important that the Host Country National Counterparts and possibly their supervisors be interviewed as well as PCVs.

- When planning the design of the workshop, choose only two or three of the most commonly expressed needs to focus on during the implementation. Do not try to cover too many topics at one workshop. If expressed needs are too broad to be covered adequately in a single IST, a second workshop may be appropriate.

- Eight or nine days seems to be adequate time to implement a complete workshop. Scheudule one day in the design for free time to provide participants a recess.

- A dual purpose facility for housing the participants as well as facilitating the training sessions is highly desirable and preferred. However, if such a facility is not available, try to arrange the location of the housing and training facility in such a way that their proximity allows for the minimum travel time from one to the other. This may require the use of a bus for transporting the trainees.

- We found that daily staff meetings were invaluable. Both an initial team building session prior to the commencement of the workshop and nightly staff meetings are a must. The nightly meetings were to review the accomplishments of that day and make the necessary and appropriate changes in the subsequent sessions.

- A training session plan for each topic of training should be prepared by the instructor in advance of the IST and made available to the staff for discussion to ensure that the topics are adequately covered and that the session flows smoothly with previous and subsequent sessions.

- When making preparations for the field trip, we cannot overemphasize the importance of careful planning. It is absolutely crucial that the plans you make be coordinated with the community leaders or institutions you plan to visit so that they understand what is to take place and how they fit into the scheme. We went through the agriculture extension service when choosing the community to work with in the Solomon Islands which proved to be very advantageous.

- As much "hands-on" (experiential learning) training opportunities as possible should be incorporated into the workshop design. This is fairly difficult in the area of agroforestry; however, if traditional or demonstration systems are available, we recommend that a short visit be arranged.

- For specific sessions: We recommend that the session on counterparts and Women in Development (WID) be scheduled as two separate one hour sessions. They are both very important issues and deserve separate attention. However at the same time, they are very much related and should be linked/bridged on the agenda.

- We recommend that the session on silvo-pastoral systems include all farm animals in general and expand on how they can be incorporated into a silvo-pastoral system. A suggestion would be to include chickens, pigs, sheep, ducks, goats, rabbits, etc. In our workshop, we dealt principally with the large farm animals. Although valuable, we felt that it was limiting; therefore the reason for expanding the scope of animals to be covered.

- Because this workshop is designated agroforestry, we suggest, depending on space availability, incorporating agriculture PCVs and their Host Country National Counterparts into the program. In some countries, we have witnessed a teaming-up of agriculture and forestry volunteers to implement very successful agroforestry projects. If people working in these two areas are trained together we feel that collaborative efforts among them could be immensely improved. Further, the added benefit of information exchange among people brought together for such a training program should serve as an additional incentive to design workshops for such a mix of PCVs.

TRAINING PROGRAM GOALS AND OBJECTIVES

GOALS

- To develop a stronger and more confident understanding and working relationship among Peace Corps Volunteers and their respective Host Country National Counterparts.
- To identify and improve needed skill areas in agroforestry, site survey methodologies and development strategies.
- To broaden the participants knowledge of a variety of potential forestry extension techniques and enable them to practice these techniques.
- To give the participants confidence in recommending and incorporating, where appropriate, traditional or new systems of agroforestry in accordance with the local needs and conditions.
- To recognize the role of women in forestry and integrate women into community analysis and project planning for a holistic approach to human resource utilization and development.
- To provide participants the opportunity for information sharing on specific forestry issues and practices in their respective countries of service.

OBJECTIVES

- Working in groups, counterparts (PCVs and HCNs) will gain an improved understanding of each other and thereby enhance their working relationship.
- Through lectures and field/site visits, participants will augment their knowledge and understanding of the environmental, economic and social implications of agroforestry practices.
- Trainees will view and discuss traditional methods of agroforestry practices in Asia and the Pacific and discuss those practiced in their respective countries.
- Analyze the environmental, economic and social aspects involved in carrying out an agroforestry project on a specific site. Participants will then prepare and present an integrated plan for the improvement of the site.
- Participants will examine various extension methodologies and experiment with a variety of extension techniques.
- Participants, through "hands-on" exercises will understand the principles of grafting and pruning fruit trees.
- Participants will gain "hands-on" experience in nursery management techniques.

AGENDA FOR
AGROFORESTRY WORKSHOP

Honiara, Solomon Islands
October 23 - 29, 1983

Saturday, October 22

1300 - 1500	Staff Meeting: Team building Session (Fillion, Weeks, Dupre, Vergara, MacDicken, Schenk and Burwell)

Sunday, October 23

1730 - 1830	Welcome - Staff Introduction (Fillion, Acting PCD Solomon Islands)
1830 - 1900	Toast
1900 - 2000	Dinner

Monday, October 24

0800 - 0815	Workshop Administration (Weeks)
0815 - 0930	Expectations (Burwell)
0930 - 1000	Goals and Objectives of Workshop (Burwell)
1000 - 1015	Break
1015 - 1115	Counterparts (Dupre, Fillion, Vergara)
1115 - 1200	WID Role/Slide Show (Dupre, Fillion)
1200 - 1300	Lunch
1330 - 1515	Concepts of Agroforestry, History and Development. Classification and Comparisons of Agroforestry Systems (Vergara)
1515 - 1530	Break
1530 - 1630	Ecology & Conservation (Schenk)
1630 - 1730	Land Use Planning (Senter)
1730 - 1745	Break
1745 - 1830	Presentation of Agroforestry Projects (Burwell)
1830 - 1900	Review & Processing (Burwell)
1900 - 2000	Dinner

Tuesday, October 25

0700 - 0745	Breakfast
0800 - 1600	Visit Agroforestry Sites. Information gathering and site observations. Lunch in the field.
1600 - 1630	Return to Hotel
1630 - 1730	Ecological, Economic and Social Advantages of Agroforestry Systems (Vergara)
1730 - 1800	Review & Processing (Burwell, Vergara)
1800 - 1900	Dinner
1900 -	Slide Presentation (Participants) Work on Agroforestry Projects Staff Meeting

Wednesday, October 26

0700 - 0745	Breakfast
0800 - 1000	Nitrogen-Fixing Trees: Role in Agroforestry Systems; Potential and Limitations (MacDicken)
1000 - 1015	Break
1015 - 1200	Nitrogen-Fixing Trees: Species Selection & Regeneration (MacDicken)
1200 - 1300	Lunch
1330 - 1500	Agroforestry Project Planning (Vergara)
1500 - 1515	Break
1515 - 1715	Agricultural Crops in Agroforestry (Dupre)
1715 - 1745	Review & Processing (Burwell, Fillion)
1745 - 1900	Slide Presentation (Participants)
1900 - 2000	Dinner
2030 -	Slide Presentations Continued (Participants) Staff Meeting

Thursday, October 27

0700 - 0745	Breakfast
0800 - 0900	Silvo-Pastoral Systems: Cattle Under Trees (Knight)
0900 - 1000	Agroforestry and Fuelwood Production (MacDicken)
1000 - 1015	Break
1015 - 1200	Sustained Production of Fodder and Fertilizer in Agroforestry (Vergara)
1200 - 1300	Lunch
1300 - 1630	Free Time
1630 - 1800	Extension: Techniques & Practices (Fillion, Dupre)
1800 - 1830	Review & Processing (Fillion, Burwell)
1900 - 2000	Dinner
2000 -	Work on Agroforestry Projects Staff Meeting

Friday, October 28

0700 - 0745	Breakfast
0800 - 0900	Economic Evaluation of Agroforestry Projects (Vergara)
0900 - 1000	Seed Collection & Storage (Schenk, Burwell)
1000 - 1015	Break
1015 - 1200	Seed Collection Exercise (Schenk, Burwell)
1200 - 1300	Lunch
1300 - 1500	Fruit Tree Grafting - Lecture (Burwell)
1500 - 1515	Break
1515 - 1630	Fruit Tree Grafting Practice (Burwell)
1630 - 1645	Break
1645 - 1815	Fruit Tree Pruning (Schenk)
1815 - 1845	Review & Processing (Fillion, Burwell)
1900 - 2000	Dinner
2000 -	Work on Agroforestry Projects Staff Meeting

Saturday, October 29

0700 - 0745	Breakfast
0800 - 1000	Agroforestry Presentations (Participants)
1000 - 1015	Break
1015 - 1200	Agroforestry Presentations (Participants)
1200 - 1300	Lunch
1315 - 1415	Agroforestry Presentations (Participants)
1415 - 1445	Counterparts (Dupre)
1445 - 1515	Review Expectations
1515 -	Evaluation of Workshop
1800 - 1900	Mixer
1900 - 2000	Dinner
2000 -	Certificates & Closure

TRAINING SESSIONS

DAY ONE

0800 - 1000 hrs.	**WORKSHOP ADMINISTRATION; EXPECTATIONS; GOALS AND OBJECTIVES**
Objective:	Participants will understand the administrative procedures for the week. They will come to agreement on the goals and objectives of the IST and understand the agenda and training methodology to be utilized.
Procedure:	o Explain the session. o Participants divide into pre-defined groups to identify individual expectations of the IST and of the workshop staff. o As a group, list expectations. o Staff then presents their perceived goals and expectations and compare them to those of the participants. o Training agenda is presented and discussed. o Modification in goals and objectives as well as the agenda are made to meet new expressed needs and a final version is agreed upon. o The Adult Learning Theory is discussed.
Resources:	Newsprint, markers, masking tape.

DAY ONE

1015 - 1115 hrs. COUNTERPARTS

Objective: To understand the importance of working in the field as a team. To develop a stronger and more confident working relationship and understanding among PCVs and their HCN counterparts.

Procedure:

- o Trainer leads discussion on what it means to be a counterpart.
- o Divide into counterpart teams (PCV & HCN) and list their motivations for working in development.
- o Small groups present lists and report on their motives. Trainer then leads discussion concerning common motives listed.
- o Trainers conduct role play between PCV and HCN simulating a counterpart team working relationship. It should be done by a female and male trainer.
- o Trainer leads discussion of role play.

Resources: Newsprint, markers, and two trainers for role play.

1115 - 1200 hrs. WOMEN IN DEVELOPMENT (WID) SLIDE SHOW AND DISCUSSION

Objective: The participants will recognize and be able to discuss the role of women in the development process and more specifically in forestry and to that end, the importance of integrating women into the community analysis and project planning procedure.

Procedure:

- o Women in Development slide show presentation.
- o Trainer leads discussion of the slide show and how it relates to women in

forestry, more specifically, women's role in forestry in the respective work sites/countries of the trainees.

- Discuss how women can be integrated into the project planning process.
- Discuss the counterpart roleplay done in an earlier session and the relationship between the female PCV and her male HCN counterpart.

Resources: Women in Development Slide Show.

1330 - 1515 hrs.

CONCEPTS OF AGROFORSTRY, HISTORY AND DEVELOPMENT; CLASSIFICATION AND COMPARISON OF AGROFORESTRY SYSTEMS

Objective: The participants will have an understanding of the history and development of agroforestry and be able to discuss and classify different agroforestry systems and state their advantages and disadvantages.

Procedure: Lecture should include:

- An historical perspective of traditional agroforestry systems beginning with slash and burn agriculture through its stabilization. Include cultural changes through time and its effect on the system of agriculture practiced.
- Several ways of classifying agroforestry systems (by spatial arrangements, by sequence and by major product).
- How different components within an agroforestry system utilize the different soil and light stratas.
- Process of selecting the appropriate combination of crops, animals and trees for agroforestry systems.
- Discussion of lecture.

Resources: Handout: New Directions in Agroforestry: The Potential of Tropical Legume Trees; Selection of Legume Trees for Agroforestry. By Dr. Napoleon Vergara.

DAY ONE

1530 - 1630 hrs. ECOLOGY AND CONSERVATION

Objective: The participants will have a general understanding of the problems, their origins and the effect that the loss of tropical forests is having on the ecology. They will then be able to discuss potential solutions and how those solutions relate to their involvement in development assistance.

Procedure: Through group discussion, led by a trainer, the participants will be able to:

- Identify the ill effects of deforestation on the ecology.
- Identify the origins/causes of deforestation both natural and those induced by humans.
- Propose and discuss possible solutions to the problems deforestation poses on the ecology and relate those potential solutions back to their particular work sites.

1630 - 1730 hrs. LAND USE PLANNING

Objective: The participants will have a working understanding of the methodology and the sequence of events that go into land use planning and its implications on project success or failure.

Procedure: Lecture should include:

- Definition of land use planning: A process of judging the best use of a piece of land to achieve the goals of the users.
- Guidelines for setting goals and objectives in land use planning. Process should include data gathering within the community concerning their needs and the parcel of land to be utilized.

- How and what kind of information to be researched in the land use planning process.
- Instructions for mapping a land use plan.

1745 - 1830 hrs.

PRESENTATION OF AGROFORESTRY PROJECTS

Objective: The participants will have a clear understanding of what the objective of the group agroforestry project is and the steps to take to reach that objective.

Procedure:

- Trainer explains to the participants that they will be conducting a site survey in a local community.
- The methodology for the site survey is briefly explained. Further the participants are informed as to the type of data to collect and who in the community is best to interview as they attempt to obtain the needed information. Participants are reminded of the morning session regarding the role of women in development.
- It is explained to the trainees that they will be expected to do an oral presentation at the end of the training.

NOTE

The original expectation was for the participants to design an agroforestry system based on information gathered during their community field visit. As a result of several group discussions throughout the training, the style and content of presentations were left to the discretion of each group. This produced some very interesting presentations ranging from the intended agroforestry plan to what would the next step be in the community analysis/information gathering process.

END OF EACH DAY REVIEW AND PROCESSING

Objective: For each participant to have a clear understanding of the day's activities and how they relate to the overall goals and objectives of the IST. To provide an opportunity for the review of the next days activities and objectives.

Procedure: Trainer leads a group discussion which should include:

- A review of each session and whether the session objectives were met.
- Discussion of any unfinished sessions.
- Feedback on how training is proceeding.
- A review of the next day's schedule and goals.

NOTE The review and processing session was repeated at the end of each day.

DAY TWO

0800 - 1600 hrs.	**FIELD TRIP TO LOCAL COMMUNITIES**
Objective:	For participants to practice extension techniques and site survey methodologies while gathering information to be used in their agroforestry reports.
Procedure:	o The large group divides into six predetermined small groups and are transported to different local communities. o Each group is assigned a trainer who acts as a passive observer during the site survey/information gathering process. This is done so that the trainers have a complete understanding of the information gathered to be better prepared for the discussion of the group presentations made at the end of training.
Resources:	Packed lunches.
NOTE	The field trip requires excellent advance planning. Those communities to be visited by the participants should be contacted well in advance and follow-up visits by the trainers should be made prior to the appointed date for the field exercise. The communities should be made aware of the process and what the trainees will be doing, do not raise the communities expectations. It can be quite disruptive to the "going-ons" of a community if a large unexpected group of outsiders descends on them without ample advance warning.
1630 - 1730 hrs	**ECOLOGICAL, ECONOMIC AND SOCIAL ADVANTAGES OF AGROFORESTRY SYSTEMS**
Objective:	The participants will have an understanding of the ecological, economic and social benefits of utilizing agroforestry systems. They will, upon return to their work sites be able to incorporate this information into their programs and extension activities.

Procedure: Lecture should include:

- o Generalized and specific ecological benefits (general: reduction of pressure on forest lands, protection of upland ecological systems; specific: reduction of soil erosion and increase in soil fertility).
- o Economic benefits for individuals, communities and entire regions through an increase in product output which should have a proportional increase in the level of farmer income.
- o Social benefits, i.e., improved rural living standards, improved nutrition and health conditions and the stabilization of upland communities.
- o Discussion.

1730 - 1800 **REVIEW & PROCESSING** (same as day one)

1800 - 1900 hrs. **SLIDE PRESENTATION**

Objective: To provide an opportunity for sharing information on the work and specific forestry projects and practices of the participants in their work site/country. This session attempts to provide an opportunity for participants to discuss the similarities of their projects and successful and unseccessful solutions applied to problems they have encountered on these projects.

Procedure: Slide show presentation and discussion is lead by three of the countries participating. This activity is repeated throughout the training program to allow participants who came with slide shows an opportunity to present them.

NOTE This was a fun activity, enjoyed by all the participants as well as the staff. It relaxed and loosened-up the participants and got more of an informal atmosphere established.

DAY THREE

0800 - 1000 hrs.

NITROGEN FIXING TREES (NFT): THEIR ROLE IN AGROFORESTRY SYSTEMS - POTENTIAL BENEFITS AND LIMITATIONS

Objective:

The participants will be able to define Nitrogen Fixing Trees and identify certain genera and species of the best potential NFTs. They will also be able to explain to farmers, the advantages and disadvantages of utilizing NFT species in their fields in agroforestry systems.

Procedure:

Lecture should include:

- o Sources of nitrogen and how it is introduced into the soil (atmospheric, biological and non-biological sources).
- o The effect of erosion on the soil and how NFTs can help prevent erosion while at the same time improving the nutrient content of the soil.
- o Taxonomy of NFTs and the three subfamilies of legumes: Caesalpinioideae, Mimosoideae, Papilionoideae.
- o The nonleguminous tree genera that fix nitrogen, prinicpally, Alnus and Casuarina.
- o The many uses of NFTs species e.g., fuelwood, fodder, timber, ornamentation, etc.
- o The advantages and disadvantages of fast growing NFTs.

Resources:

Handout: Nitrogen-Fixing Tree Resources: Potentials and Limitations. By J.L. Brewbaker, R. Van Den Beldt and K. MacDicken.

DAY THREE

1015 - 1200 hrs. **NITROGEN FIXING TREES: SPECIES SELECTION AND REGENERATION**

Objective: The participants will understand the importance and methodology of species selection. They will be able to propogate NFTs by various methods and understand proper management of seedlings both in the nursery and on plantations.

Procedure: Lecture should include:

- The methodology of proper species selection; environmental requirements, community needs and purpose of planting.
- Seed selection and preparation.
- Different methods of propagation; nursery (both in containers and bare root), vegetative propagation, and direct seeding.
- Nursery management and the use of bacterium and rizobium.
- The importance of weed control and the nutrient requirements of NFTs in plantation management.

1325 - 1500 hrs. **AGROFORESTRY PROJECT PLANNING**

Objective: The participants will have a working understanding of the "systems" approach to planning.

Procedure: Lecture should include:

- Definition of a system: "a whole which consists of component parts that are interdependent and interacting such that a change in one component results in a chain of reactions which results in changes in the other components and in the whole".

- Definition of planning: "the careful process of identifying and selecting the best alternative means for achieving a set of objectives and goals".

- Steps in systems planning (emphasis should be made that throughout the planning process, members of the community participating in the project should be included in each step):

  a) Identify goals and objectives,

  b) determine problems and constraints,

  c) identify all possible options for achieving goals,

  d) narrow options down to the practical and practicable,

  e) using technical, economic and social data gathered within a community; compare remaining options,

  f) select with the community the best option.

- Emphasize the importance of looking at existing traditional agroforestry systems when selecting final project plan.

- Participants should be reminded that agroforestry is an option, it is not a panacea.

Resources: Handout: New Directions in Agroforestry: The Potential of Tropical Legume Trees; Initial Tasks in Agroforestry Projects. By Dr. Napoleon Vergara.

DAY THREE

1515 - 1715 hrs. **AGRICULTURAL CROPS IN AGROFORESTRY**

Objective: The participants will be able to select compatable food, fodder and tree crops to best fit expressed needs of community and growing conditions of the area. They will have a general technical understanding of the production of food crops.

NOTE The actual planning process of selecting the appropriate components in an agroforestry plan has already been discussed. This session is focused more on the technical aspect of food crops production. Lecture should be delivered by an agronomist.

Procedure: Lecture should include:

- How to develop a management plan for agricultural crops and how it relates to and complements the management plan of tree crops (i.e., farmer is more sensitive to weeding food crops than tree crops and will therefore indirectly weed tree crops when weeding food crops).
- A discussion of different crop characteristics that should be taken into consideration when planning combinations (e.g., shade tolerance, rooting depth, rate of growth, height at maturity, nutrient requirements [nutrient producer or consumer], watering needs).
- Emphasis should be made again that final selection process should be heavily geared towards the expressed needs and eating habits of the community.

1715 - 1745 **REVIEW & PROCESSING**

DAY FOUR

0800 - 0900 hrs.

SILVO-PASTORAL SYSTEMS: CATTLE UNDER TREES

Objective: For the participants to have a working knowledge of and be able to discuss the integration of animals (both large and small) into an agroforestry system. In this relationship the animals can serve as an active component, e.g., grazing in a field under trees, or as a passive component, e.g., utilization of leaf litter as fodder.

Procedure: Lecture should include:

- Discussion of animals most commonly found on farms within the training participants countries and the feeding and grazing needs of those animals.
- How those feeding and grazing needs can be met through agroforestry, e.g., planting pasture grasses under trees; using hedgerows of leguminous forage trees, i.e., leucaena; planting shade trees in existing pastures etc.
- The symbiotic relationships between certain animals and plants.
- The nutritive and economic benefits of silvo-pastoral systems.

DAY FOUR

0900 - 1000 hrs. **AGROFORESTRY AND FUELWOOD PRODUCTION**

Objective: To provide the participants with information on the production of fuelwood in forest plantations, and integrating this information into agroforestry systems. They will understand the difference between tree production for fuelwood as compared to traditional forestry plantations and the intense management needs of these fuelwood systems.

Procedure: Lecture should include:

- The difference between traditional forestry plantations and fuelwood production; fuelwood production requires shorter rotations, higher planting density and more intensive management practices.
- The basics of management practices; i.e., managed more like agricultural crops; when to harvest, how often to harvest etc.
- The importance of proper species selection to suit the characteristics and capabilities of the land.
- Land availability should be determined with the farmer. It may be decided to plant in blocks or as live fences, hedges or on other underutilized areas.
- The process of choosing species and the importance of setting up trial plots for growth rates - How to set them up and evaluate their results.
- Two different aspects of sustainable plantation management: fertility management and soil erosion control.

Resources: Handout: Production of Fuelwood and Small Timber in Community Forestry Systems. By Kenneth MacDicken

DAY FOUR

1015 - 1200 hrs.

SUSTAINED PRODUCTION OF FODDER AND FERTILIZER IN AGROFORESTRY

Objective: The participants will have an understanding of the management practices in agroforestry to achieve sustained fodder and fertilizer production.

Procedure: Lecture should include:

- Distinction between food products, wood products and green biomass.
- Discussion of the best fodder producing tree species.
- Methods of fodder harvest; direct and indirect and the associated advantages and disadvantages.
- The concept of carrying capacity - carrying capacity of a land area for livestock as it relates to fodder availability.
- Timetable for trimming trees for best production of fodder and/or green manure, compared to the production of fuelwood.
- Economics of trimming trees for fodder and/or green manure production.
- Impact of solar energy and soil nitrogen on fodder production.
- Acacia and other fast growers and precautions that should be taken if they are included in an agroforestry system geared to fodder production (non-palatability).
- Effects of green manure consumption on cattle; specifically mimosene in Leucaena and hair loss in cattle and swine.

Resources: Handout: New Directions in Agroforestry: The Potential of Tropical Legume Trees; Sustained Outputs From Legume-Tree-Based Agroforestry Systems. By Dr. Napoleon Vergara.

DAY FOUR

1200 - 1630 hrs. **FREE TIME**

Objective: Participants were given this time to relax, tour the city of Honiara, swim, scuba dive, snorkle, work on their agroforestry projects, and in general, provide a break in the hectic training schedule.

NOTE This time was not originally scheduled into the agenda; however, due to the intensive schedule, we thought that this would be an excellent replacement for a session which was combined with another.

1630 - 1800 hrs. **EXTENSION TECHNIQUES AND PRACTICES**

Objective: The participants will have an understanding of what it means to be an "extensionist" and be able to discuss what is involved in the extension process.

Procedure: Lecture should include:

- o A definition of an extensionist: A person who helps people understand; a middle person between farmers and farmers, farmers and researchers, farmers and other extensionists, farmers and organizations.
- o Steps in the extension process:
  - information gathering,
  - planning (with farmer participation),
  - communicating (how to communicate information to others),
  - education and training,
  - implementation of the plan (either with an individual farmer, a group or community),
  - follow-up and evaluation (stress the importance of maintaining contact with the people after implementation).

o Communication methods (ask participants what they have used);

  - individual contact,
  - group meetings,
  - demonstrations in the field,
  - demonstration plots,
  - field days,
  - mass media,
  - materials and audio visual aids (pamphlets flyers, posters, slides, movies, etc.).

o Dicussion should include techniques that the participants have utilized both successfully and unsuccessfully. A link between the material presented and its importance/relevance to the trainee's agroforestry projects should be made.

1800 - 1830 **REVIEW & PROCESSING**

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DAY FIVE

0800 - 0900 hrs. **ECONOMIC EVALUATION OF AGROFORSTRY PROJECTS**

Objective: The participants will understand the methodology of determining the economic feasibility of agroforestry projects and therefore have the capability to determine whether a project should be implemented now, at a later date, or not at all.

Procedure: Lecture should include:

- An explanation of the need for economic evaluation, both preproject evaluation to determine if a project is economically feasible and postproject evaluation to ascertain whether the project is a success or failure.
- Factors that go into an economic evaluation:
  - Scope of evaluation: level of evaluation, individual family plots, entire community or entire watershed.
  - The time horizon: the time span to be included in the calculations of economic feasibility/evaluation of a project.
  - Data collection: information on all physical inputs, outputs and residuals generated by the project.
  - Valuation: the worth attached to benefits and costs.
  - Discount rate: a determination of present value of all costs and benefits that will occur throughout the life of the project.
- Economic evaluation techniques with simple examples.

Resources: Handout: New Directions in Agroforestry: The Potential of Tropical Legume Trees; Economic Evaluation of Agroforestry Projects. By Dr. Napoleon Vergara.

DAY FIVE

0900 - 1200 hrs.

SEED COLLECTION AND STORAGE (LECTURE AND FIELD TRIP)

Objective:

Participants will have a working knowledge of several methods of collecting and storing seeds. To provide an opportunity to practice this newly acquired skill of seed collection.

Procedure:

Trainer gives lecture and leads group discussion:

- Methods of seed collection.
- Different types of seeds, e.g., fruit, hard coat, soft coat, winged, pulpy, etc.
- Various ways to store seeds and precautions that should be taken; i.e., precautions against fungal infections, insect damage, heat and frost damage, etc.
- Field trip to collect seeds.

NOTE

A location should be selected prior to the field trip. There should he a variety of tree species with at least a few of them in the seed bearing stage of development if possible.

1300 - 1815 hrs.

FRUIT TREES - GRAFTING AND PRUNING: "HANDS ON" PRACTICE

Objective:

The participants will be instructed in the selection of proper grafting materials (scion, root stock) and be able to graft fruit trees using a couple of methods. They will understand the principals and importance of pruning trees.

Procedure:

Lecture and demonstration should include:

- Explanation of the purpose and advantages of grafting fruit trees;
    - to achieve desired variety of fruit with stock adapted to local conditions,

- to gain time - grafted trees begin bearing fruit earlier than trees produced directly from seeds,
- to assure genetic purity,
- for repair purposes - renewing an old tree or repairing girdled trunks caused by rodents or mechanical damage.

o The process of selecting proper root stock and scions for grafting. Point out those characteristics desired in both.

o Review of the principles of pruning;

- space for every branch and a branch for every space,
- watch the timing - generally in the lowest growth period (dormancy) of the tree,
- prune so that the tree can heal - clean cuts, no projecting stumps - so that rain will not collect in the cut.

o Practice both grafting and pruning.

Resources: Fruit tree seedlings, scions, grafting knives, sharpening stone, horning oil, pruning shears.

NOTE It is desirable to have actual fruit tree seedlings to graft. Make arrangements to get them prior to the start of training.

1815 - 1845 REVEIW & PROCESSING

DAY SIX

0800 - 1415 hrs. AGROFORESTRY PRESENTATIONS BY PARTICIPANTS

Objective: To provide an opportunity for the project groups to present their final agroforestry project to the large group for discussion, critique and feedback.

Procedure: Forty-five minutes is allotted to each group to give their presentation. The format of the presentation is left to the discretion of each group. There should be time allocated for questions and feedback.

1415 - 1515 hrs. REVIEW OF EXPECTIONS & THE COUNTERPART RELATIONSHIP

Objective: To provide an opportunity to review the importance of working as a team and how it is relevant to the subjects covered in the workshop. To review the original goals and expectations of the workshop and ensure that they were met to the full satisfaction of the participants.

Procedure: Trainer leads a discussion to review the importance of working as a team in the field. Trainer also puts up the original flip charts with the participant's goals and expectations and reviews them.

Resources: Original flip charts with participant's goals and expectations.

EVALUATION OF TRAINING WORKSHOP

On Saturday, October 29, the last day of the workshop, written evaluations of the IST were requested of the participants. A prepared evaluation form (appendix J) was distributed to the participants soliciting responses to the overall effectiveness of individual exercises, the training staff's performance and the overall success of the workshop agenda in meeting the established goals.

We have provided a chart (appendix K) with the rating scale used during the evaluation process. On that chart, below each number rating of one to five, five being the best, a percentage is assigned designating the proportion of the participants that rated the exercise at that level.

Of special note - in the opening session on expectations, almost 70% of the participants agreed that a good starting point in any training exercise is for the staff to solicit input from participants on the training syllabus. Further, it was felt that the flexibility of the training agenda and the staff's willingness to incorporate participants' suggestions served as a good ice-breaker.

Those sessions most enthusiastically received are as follows:

- Expectations - The participants rated the session on expectation among the highest as previously stated. Comments on the session ranged from a "necessary component" to a few that indirectly called it a "waste of time." The vast majority of the respondents did receive the session well and rated it highly.

- Counterparts/WID - Overall, this session was rated highly as to presentation, content and utility. One participant commented, "good chance to hear about the motivations of our counterparts...to give us a better understanding of one another." The slide presentation on Women in Development was quite a success, well received and highly praised for its merit because of the inclusion of women and the recognition of their indispensable role in development.

- Concepts of Agroforestry - Presented by Dr. Napoleon Vergara, was rated across the board at fours and fives. Dr. Vergara's presentation ranked among the best received by the participants; they expressed profound pleasure at having "met" and been under the instruction of "the expert." Participants felt that more time should have been devoted to this topic.

- Ecology - This session was given a rating of four by 50% of the participants. The overall reception by the group of this topic was good although it was felt that greater depth and more specificity would have made the session more beneficial. The participants understood the rationale for the simplistic approach which in effect was the only approach the staff could take given the time, group size and participant's work site variations. Seemingly, a session on Ecology will, in future, be better suited to single country ISTs or multi-country ISTs with identical environmental conditions (as can be seen in some of the Sahelian countries of Africa).

- Land Use Planning - Although the session on Land Use Planning received high evaluation marks from the trainees, comments reflected a general feeling that this session had shortcomings and drawbacks overall. One volunteer suggested that the session was redundant, perhaps due to the simplistic stepwise directives given on planning and implementing land use, something most forestry volunteers would have previously received during PST or ICT. Nontheless, land use planning should be included in future ISTs if the need exists, but should be better structured for a generic overview geared principally towards agroforestry.

- Ecological, Economic and Social Aspects of Agroforestry - This session was also lead by Dr. Vergara. Once again, he received high ratings from the participants, especially for his manor of presenting the subject matter, very clear and precise. One participant liked that he presented both the advantages and disadvantages, while another stated that he "tended to gloss-over the social impacts of agroforestry for the sake of selling the concept on an economic and ecological basis. The general feeling was that such a broad, worthwhile topic should have been allotted more time.

- Nitrogen Fixing Trees I & II - Kenneth MacDicken made two presentations on the pros and cons as well as the latest advances in the use of nitrogen fixing trees in agroforestry schemes. On our rating scale of one to five, the two combined presentations received an average rating of four at 42.5% and of five at 45%. Actually, Nitrogen Fixing Trees I was rated in the five slot by the greatest percentage of participants (48%) than any other session. Part of the reason for this was the delivery format utilized by Mr. MacDicken. It was apparent that he tailored his presentation appropriately to the technical level of the target audience maximizing its effectiveness. This is important when a technically oriented lecturer presents his/her subject to a not as educated audience.

- Agroforestry Project Planning - This session, devoted to the systematic development of an agroforestry plan, stimulated much discussion, exchange and country specific input from the trainees. Factors of primary consideration when planning any development project and issues to be researched related to the plan were brought to light. Also discussed were the steps to be taken in the planning process and the importance of including the people who will benifit from the project in all the steps. It proved to be an outstanding and stimulating discussion and clearly demonstrated the need for project planning in general and planning agroforestry projects, the focus of the workshop, in particular. On the rating scale, 57% of the trainees placed this session at a four.

Agroforestry and Fuelwood Production; Sustained Production of Fodder and Fertilizer in Agroforestry; Seed Collection; Grafting; Pruning and Agroforestry Projects along with those discussed above received the highest ratings during the evaluation of the workshop. The apparent conclusion to be drawn from the evaluative comments on the previous seven sessions is that the participants had a real need for and interest in the specific areas covered. Further, it is our conclusion that the methodology utilized for information and skill transfer met the needs of the participants.

In general, the participants felt that all of the foregoing sessions, with the exception of expectations and counterparts/WID could have been better if more time had been allowed. Other topics on the training agenda not covered specifically in this section were rated below average. The most frequent comments on the below average and low ratings were: "Too hurried", "too technical" to "not enough specifics", "more 'hands-on' training" and a few "waste of time."

Other concerns expressed by the participants included:

- A need to allow more time on the agenda for information sharing among participants. It was intended that the slide presentations by the participants would stimulate and satisfy this need; however, it is apparent from the comments that additional time was needed.
- That lecturers designated as experts should be experts in their field with previous training experience. This comment had a dual meaning. First, an expert should have a thorough understanding of the technology they are to cover. Second, they should, as previously stated, be aware of the composition of the target audience so that the delivery of information is free flowing and easily absorbed. As these ISTs are usually short and fully planned well in advance of delivery (although subject to change), time, which is of the essence could easily be wasted if a topic inadequately covered has to be rehashed in an attempt to deliver information that was poorly presented the first time around.
- That there should be a greater emphasis on extension approaches and techniques. The single most important function of any volunteer is to effect skill transfer (extension) in an effective and culturally accepted manner. Therefore, participants felt that more time and consideration should be given this subject.
- That the intensity of the training be decreased by increasing the overall length of the workshop.

In closing, the evaluation provided the IST planners, implementing staff and the Office of Training and Program Support an opportunity to assess the degree to which areas of training requested had been or not been satisfied. To this end, better and more effective training during the period of service of the volunteer can be delivered based on their evaluation and suggestions for improvement of future in-service training workshops.

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APPENDIX A

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APPENDIX C

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APPENDIX D1

NEW DIRECTIONS IN AGROFORESTRY: THE POTENTIAL OF TROPICAL LEGUME TREES

SELECTION OF LEGUME TREES FOR AGROFORESTRY

Edited by

Napoleon T. Vergara

Prepared by a
Working Group on Agroforestry
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June 1982

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The Agroforestry Working Group drew heavily from materials prepared and presented by twenty-five professionals from eleven countries at the Agroforestry and Fuelwood Production Workshop held at the East-West Center November 12 to 20, 1982. This activity was partially supported by a grant from the United Nations University.

NEW DIRECTIONS IN AGROFORESTRY: THE POTENTIAL OF TROPICAL LEGUME TREES

Selection of Legume Trees for Agroforestry

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THE ECOLOGICAL ROLE OF TREES IN SUSTAINABLE AGROFORESTRY: A REVIEW

Intensive cultivation of shallow-rooted annual food crops on hilly land has been seen to result in rapid soil erosion and reduction of farm productivity, in addition to other undesirable off-farm effects such as siltation of rivers and reservoirs, uneven stream flow, and pollution of water. In some places, such as southern China, Java and Bali (Indonesia), and Northern Luzon (Philippines), erosion is controlled and productivity is maintained by terracing the slopes. This approach, however, requires large amounts of labor and capital inputs, which are scarce among upland farmers. Consequently, the cheaper and more readily implementable approach of using trees for upland stabilization is often more appealing to, and can be more readily adopted by, hill cultivators.

There are three important ecological roles of practically all tree species in upland farming: (1) stabilization of hilly land, (2) maintenance and improvement of soil fertility, and (3) improvement of microclimate.

Stabilization of Hilly Land

The generally wide-spreading and deep-penetrating roots of trees serve as soil binders that reduce the tendency of soil on slopes to move downward with surface runoff. The surface roots and tree stems, especially when trees are planted as contour hedges in agroforestry, impede the flow of surface water, reducing its speed and erosive force. The tree crowns and the accumulated layer of litterfall on the soil surface break the impact and reduce splash-erosion effects of heavy raindrops. Root penetration into the subsoil increases water infiltration and absorption, reducing the volume and erosive ability of surface water. All of these factors together increase soil stability, reduce soil erosion, and minimize soil and nutrient depletion.

Maintenance and Improvement of Soil Fertility

Rapid soil and nutrient losses from sloping land can be remedied by trees so that soil fertility and productivity can be maintained and even improved. With their long tap roots, trees recover nutrients lost to the subsoil through leaching and infiltration and recycle them to the surface in the form of litterfall that decomposes and release the nutrients back to the surface soil. Nutrients lost to rivers and lakes through leaching and surface runoff cannot be recovered but are replaced when the trees absorb minerals just released by newly weathered parent rocks in the lower soil strata and "pump" them to the surface in the form of litterfall. The accumulation of decayed leaves and branches increases the organic matter content and reduces the bulk density of the soil, making it better suited to cropping and production.

Improvement of The Microclimate

Partial shading and the mulching effect of litter provided by trees in agroforestry reduce solar radiation on the soil surface, thereby minimizing effects of higher temperatures such as drying and hardening of the soil. Availability of sufficient amounts of soil moisture, and the maintenance of soil temperature at an optimal level enhances microbial activity for decomposing litter and releasing nutrients to the soil for plant use.

THE SPECIAL ROLE OF LEGUME TREES IN SUSTAINABLE AGROFORESTRY

Roles Similar to Those of Other Trees

Legume trees contribute to sustainable agroforestry production in much the same way that other tree species play their useful ecological roles as outlined previously. Some legume trees, however, have been noted to function better than others. For example, certain legumes have unusually long tap roots (e.g., *Leucaena*) so that they have a much better capacity to anchor and stabilize the soil, and a greater ability to recover and absorb moisture and nutrients from the deeper subsoil. Legume trees usually have small leaflets (e.g., *Sesbania*, *Gliricidia*, *Leucaena*), which decompose more rapidly and enable the nutrients to return more quickly to the soil surface to maintain productivity. Furthermore, small leaves allow sunlight to reach interplanted low-level food crops.

The Special Role: Biological Nitrogen Fixation

The most important role of legumes that other tree species cannot perform as effectively, if at all, is in supplying nitrogen to both the trees themselves and to the interplanted food crops. Since nitrogen is highly essential to plant growth

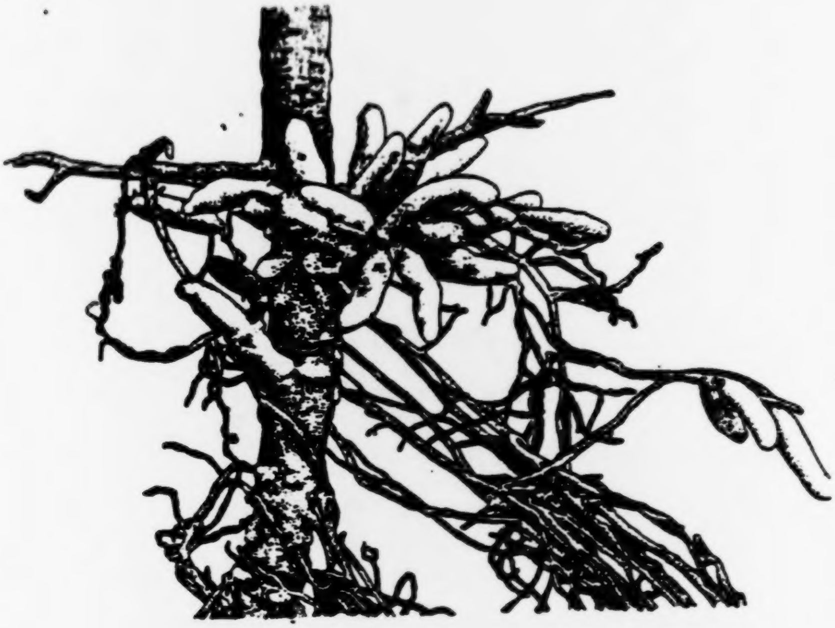

Figure 1. Legume tree roots with nodules formed by Rhizobia.

and yield, and since it is often obtainable only in the form of expensive commercial fertilizer which subsistence farmers can barely afford, the nitrogen supply from legume trees, at little or no cost to these hill farmers, is important.

There are a few nonlegume trees, such as Casuarina, Alnus and Parasponia, that are known to possess nitrogen-fixing abilities. However, the greatest concentration of nitrogen-fixing trees is found in the legume family.

Nitrogen abounds in the atmosphere and in the soil, but it is in forms that are not useful to plants. It must first be converted into a soluble form (ammonia) before the plants can absorb and use it. Most legume trees have the capacity to convert atmospheric nitrogen to ammonia (biological nitrogen fixation or BNF) with the assistance of certain bacteria (*Rhizobia*) with which they are symbiotically related. The bacteria enter and infect the root hair and the root cells divide rapidly at the point of infection, causing root nodules to be formed (Figure 1). The *Rhizobia* live in the center of the nodule, which is the site of nitrogen fixation. The formation of nodules and the production of a red pigment by the *Rhizobia* are indicators of nitrogen fixation. For this reason, root nodules that are reddish inside indicate ongoing fixation. If nodules are white inside, they are infected roots with no ability to fix nitrogen.

The amount of nitrogen fixed varies with the tree species, with conditions on the site, and with the *Rhizobia* present. *Leucaena* has been observed by various researchers under different conditions to yield from 70 to 500 kg of nitrogen per ha per year.

Obstacles to Biological Nitrogen Fixation

There are certain factors that impede nitrogen fixation by legume trees. The first is that some *Rhizobia* strains can interact symbiotically with certain tree species but not with others. Because of this specificity, legume trees may fail to nodulate and fix nitrogen for want of a suitable strain of *Rhizobia*. The second factor is the site selectiveness of some *Rhizobia*. For example, some cannot cause nodulation in acidic soils, and therefore fixation cannot occur. A third factor is that some Rhizobia are susceptible to competition from other microorganisms, and when they are mixed with other strains, they die or are unable to fix nitrogen.

Measures to Enhance Biological Nitrogen Fixation

The impact of the factors that are known to inhibit nitrogen fixation can be minimized. One way to do this is by identification, isolation, and use of Rhizobia strains that suit a given legume tree species. Farmers, of course, are not trained to do this themselves, but there are research institutions (e.g., Nitrogen Fixing Tropical Agricultural Legumes Project of the University of Hawaii) that do these tasks and make available to developing countries samples of the strains and the technology of culturing them and methods of inoculating seeds or seedlings of suitable tree species with them. Whenever Rhizobia inoculum is available locally at affordable prices, farmers should be encouraged to use it to maximize the nitrogen-fixing capacity of the legume trees and maximize the yields of both the trees and the interplanted food crops.

In many cases, "packaged" Rhizobia strains are either not available locally or are available but priced beyond the reach of hill farmers, most of whom are subsistence farmers with little or no cash incomes. In this instance, the best alternative is for the farmers to obtain soil from areas where the desired legume tree is growing well and producing nitrogen satisfactorily as shown by the presence of reddish nodules. This soil will contain Rhizobia suited to the tree. When seeds are planted on this soil, natural inoculation with the Rhizobia is achieved. Another possible means is to gather seedlings growing naturally under mature trees in Rhizobia-infected soil. The ball of earth around the seedling's roots will assure that Rhizobia are introduced into the new planting site.

While these inoculation techniques are cheap enough to be affordable to subsistence hill farmers who wish to embark on legume-tree-based agroforestry, there is a problem that may arise. Other microbes, which may not be beneficial or which might compete with the desired Rhizobia, may likewise be introduced to the new site. Furthermore, the Rhizobia, while capable of enhancing nodulation and nitrogen fixation, may not be the best strain for a given tree species.

Another method of enhancing biological nitrogen fixation is by modifying soil acidity levels. A simple field test may be used to determine soil pH levels. A soil sample from the farm is dissolved in distilled or rain water (so that the water will be neutral) and tested. (See Appendix for testing methods.)

If the soil is too acidic for the desired tree species, it can be corrected by applying lime. Instead of spreading lime over the whole area, which would be expensive, the farmer can apply crushed limestone pellets prior to planting, with a seed embedded inside each pellet. If lime is unavailable or is too expensive, it may be simpler for the farmer to select a tree that thrives in acidic soils, such as Acacia auriculiformis.

The Use of Biologically Fixed Nitrogen by Trees and Food Crops

The nitrogen fixed by legume trees benefits three groups of plants in agroforestry: (1) the legume trees themselves, (2) other trees planted close to the legumes, and (3) the food plants intercropped with the trees.

The legume trees benefit because the nitrogen is already in their root systems and can be utilized readily by the plant cells for synthesis into amino acids, proteins, and other nitrogen-containing compounds that are needed in plant growth. This is the reason for the relatively rapid growth of trees that have nitrogen-fixing capacities.

The intercropped food plants and other trees benefit because the legume tree leaves, which either fall naturally or are cut regularly by the farmer and spread among the food plants as green manure, decompose and release nitrogen and other elements to be used by the crops. About 60 percent of this released nitrogen is lost to the atmosphere (denitrification) or to the subsoil and streams (leaching), leaving only 40 percent available to the crops. Since this nitrogen supply is virtually free and it comes from a renewable and sustainable source (trees), however, it is more cost-effective than applying commercial fertilizers.

BASES FOR SELECTION OF LEGUME TREES FOR AGROFORESTRY

While it is clear that legume trees afford many social and economic benefits to agroforestry, species to be used must be selected carefully for each agroforestry project in order to maximize their contribution to its success.

Most legume trees are deemed useful to agroforestry because they have three important characteristics in common: rapid growth, which means early harvest and greater yield per hectare per year; nitrogen-fixing ability, which supplies virtually free nitrogen fertilizer; and a multipurpose nature. When selecting species for a particular project, therefore, additional criteria must be used. Important considerations should include:

1. Ecological conditions in the locality;
2. Compatibility with locally preferred food crops;
3. Markets for, and uses of, the tree products;
4. Sociocultural characteristics of the people; and
5. Availability of planting stock.

Local Ecological Conditions

Each upland agroforestry site is unique and varies from others in soil characteristics, elevation and temperature, moisture, and other ecological factors. Similarly, each legume tree species differs from others in site requirements. If an agroforestry project is to succeed, the trees must be selected so that their site requirements match existing local ecological conditions, as enumerated here:

1. Soil quality--Some hill farms may be nutrient-rich and contain a high percentage of organic matter (humus), especially if they have been newly converted from primary forests or forest fallow through logging or slash-and-burn operations. Almost any tree can be grown on such sites. On the other hand, most hill farms have long ago been deprived of protective forest cover and may have been used abusively. In such cases, the soil is likely to be shallow and depleted, compacted, rocky and nutrient-poor, and it is usually covered by hardy grasses (e.g., *Imperata*). Under this degraded condition, only the species known to be hardy enough to withstand poor soils could and should be planted, such

as Acacia auriculiformis and Calliandra calothyrsus (see Table 2). Other species with less tolerance for poor soils may be planted, but only after expensive addition of commercial fertilizers.

2. Soil pH—There is a wide variation in soil pH among hilly lands. Those with limestones, for instance, are alkaline and have high pH values, while the badly eroded and leached grasslands are often acidic and are lower than pH 7. After determining soil pH ratings either from local soil surveys (if available) or by conducting a simple litmus test, the farmer may choose tree species for his farm. For acidic soils, Acacia auriculiformis and Acacia mangium may be used. For alkaline soils, on the other hand, Leucaena or Sesbania may be planted. Calliandra is more or less neutral with regards to pH (see Table 2).

3. Elevation and temperature—Within the tropical zone, site elevation heavily influences temperature. For this reason, altitudinal limits for trees are in fact temperature limits. For example, species that require or can only thrive in high temperatures (e.g., Cassia siamea) must be planted at low elevations (e.g., not higher than 500 m), while those that thrive in, or can tolerate cool temperatures can be planted at higher elevations (e.g., Acacia mearnsii). Because latitude or distance from the equator likewise affects temperature, altitudinal limits for species will vary depending on the latitude of the site. For instance, in the northern Philippines (latitude about 20° N), Leucaena can be grown only up to about 400 m, while close to the equator, in Papua New Guinea (latitude about 5° S), the same species has been observed to grow well up to 1,200 m.

4. Soil moisture—This factor is directly influenced by rainfall intensity and seasonal distribution. Legume tree distribution is, in turn, influenced by soil moisture. In the wet tropics, species that can stand rainfall of 1,500 mm or greater per year (e.g., Gliricidia sepium) may be suitable. In the arid tropics (Africa, South Asia) drought-resistant species (e.g., Prosopis spp., Albizia lebbek) may be selected. Because rainfall in most areas is seasonal, species to be planted must have a wide range of moisture adaptability ranging from drought-resistance to ability to survive temporary water logging. Many tree legumes have this quality (Table 2).

Compatibility With Locally Preferred Food Crops

Upland farmers have their own nutritional preferences which, to a certain extent, are influenced by sociocultural factors and by the natural environment in which their food crops are raised. In wet lowlands, for example, farmers raise and eat paddy rice. In dry uplands, on the other hand, less moisture-demanding cereals such as corn or upland rice may be cultivated. In regions where winds are relatively calm, farmers may grow more crops that have above-ground products. In areas severely affected by strong winds, however, they may cultivate root crops. Once affinity for given food crops is established, the farmers hardly change crops to suit the intercropped trees. Instead, trees are selected that are compatible with the food crops.

Different food crops have varying requirements for sunlight, moisture, temperature, and nutrients. Thus, they will react in different ways when interplanted with various trees, which themselves have dissimilar characteristics. Some food crops, such as upland rice, are light-demanding. If this characteristic is known beforehand, the farmer may select tree species that have thin canopies that will allow as much sunlight as possible to reach the rice crop, and to space trees as widely as possible so as not to defeat the yield-increasing purposes of integrated tree-food cropping. On the other hand, food crops exist that have a tolerance or need for partial shade in order to be productive. Coffee and cocoa, as well as *Dioscorea*, are well known for their partial shading needs and tolerances. In this case, legumes with denser leaves, such as Acacia and Calliandra, may be chosen for intercropping, or thin-canopied species (e.g., Albizia) could be spaced more closely.

Food crops benefit from the nitrogen supplied by leaf drops or herbage of nitrogen-fixing legume trees with which they are intercropped. It has been observed that there are certain food crops, however, such as rice and coffee, which, when supplied excessively with nitrogen fixed by trees, grow rapidly but fail to bear flowers and seeds. Clearly, the legume tree compatible with these crops should be one with a lower level of nitrogen yield.

In order that the trees will not compete with, and deprive, the food crops of nutrients and moisture, deep-rooted species must be chosen for agroforestry use so that the annual food crops will subsist on the moisture and nutrients on the top soil layer while the trees will absorb those in the lower soil horizon.

Use of and Market for The Tree Products

There are many products or end uses for legume trees grown on agroforestry farms: fuelwood, poles, and pulpwood from the stems and branches; food and fodder from the foliage and fruits; and fertilizer (green manure) from the leaves. In general, because many upland farmers cannot afford to wait long and must harvest their trees early, the wood products they extract are small and usually would not be suited to the commercial production of sawn timber and plywood. Thus the tree branches may be used only as fuelwood, poles, or pulpwood.

The intended principal end use or combination of end uses will influence the selection of legume-tree species. For example, if the principal use is domestic fuelwood, the tree species selected must be: (1) straight-grained for easy splitting; (2) hard so as not to burn too quickly; (3) easy to ignite; and (4) not smokey when burned. Such legume species as Calliandra, Leucaena, and Gliricidia may be chosen.

If the end use is poles for fencing or for propping up fruit-heavy banana plants on commercial plantations, as in the southern Philippines, the species must have long, straight, strong, durable stems. Leucaena appears to be a suitable species.

If the wood is intended for sale to a pulp and paper factory, the wood must be light-colored, long-fibered, light-weight for easy handling, and easily debarked. Albizia falcataria is an appropriate species to raise for this purpose.

Finally, if the principal product is fodder, a species with palatable leaves and a rapid rate of leaf regrowth after cutting, such as Calliandra or Leucaena, may be selected.

Availability of Planting Stock

A tree species may possess all the characteristics highly desired by farmers, but if seeds, seedlings or cuttings for planting are not readily available, that species may not be adopted. A case example is the Giant Leucaena from Hawaii. At the early stage of its distribution, its incredibly high growth rate so impressed Southeast Asian farmers they created such a large demand that not enough seeds were available and seed prices soared beyond their reach. In the end, most of the farmers settled for the bushy or "dwarf" variety of the species, which is not as productive as the "giant."

CHARACTERISTICS OF SOME NITROGEN-FIXING LEGUME TREES

The Legume Family: A Brief Description

The legume or bean family, consisting of about 18,000 species, is one of the largest plant families and also one of the most useful: it includes many of the protein-producing agricultural crops (e.g., winged beans, mung beans) and a number of the beautifully grained tropical hardwoods that are in great demand for furniture and interior panelling (e.g., Pterocarpus, Intsia).

Two subfamilies, Mimosoideae (about 2,800 species) and Caesalpenioideae (also about 2,800 species) are composed largely of woody plants and therefore could be important contributors of species to the forestry component of agroforestry systems. A large majority of the Mimosoids (at 98 percent), such as Leucaena and Calliandra, are capable of fixing nitrogen from the atmosphere. Only 30 percent of Caesalpinioids have the capability, however.

At present, legume trees are known to contribute five major economic products: food derived from fruits, flowers, and leaves; animal fodder from the protein-rich leaves; fertilizer from the nitrogen-rich litterfall; fuelwood from stems, tops, and branches; and timber from the main stem.

A few limitations and negative aspects of fast-growing, nitrogen-fixing legumes must be understood clearly by farmers and other users so that they may take appropriate action to avoid or minimize their impact on farming activities.

Tables 1-3 show in summary form the characteristics and descriptions of selected legume trees. Table 1 is a description matrix of some important legume trees drawn from various references. Table 2 shows the uses and adaptability of certain species and is based on a scale developed during the University of Hawaii network trials. Table 3 gives the properties of some nitrogen-fixing tree legumes.

Table 1. Ecological Requirements, Impacts, Uses, and Management of Nitrogen-Fixing Legume Trees

Items	*Cassia siamea*	*Acacia auriculiformis*	*Pithecellobium dulce*	*Mimosa scabrella*	*Prosopis alba*
Species identification					
Scientific name	*Cassia siamea*	*Acacia auriculiformis*	*Pithecellobium dulce*	*Mimosa scabrella*	*Prosopis alba*
Synonym			*Mimosa dulces*	*Mimosa bracatinga*	
Common name	Yellow cassia, muong, minjri, kassof-tree angkanh, cassia		Manila tamarind, Madras torn, quachamil, kamachi blackbead, opiuma (Hawaii)	Bracatinga	Algarrobo blanco, tacu, ibopi
Distribution					
Country(ies) of origin	Southeast Asia from Indonesia to Sri Lanka	Papua New Guinea, Torres Strait Islands, Northern areas of Australia	From the Pacific slopes of Mexico and S. Cal. thru all of Central America to Colombia and Venezuela	Parana region of Southeastern Brazil	
Current geographic location	Southeast Asia, West Indies, Central America, Florida, East and West Africa; Southern Africa	Papua New Guinea, Torres Strait Islands, North Australia, Indonesia, Tanzania, India, Malaysia, Nigeria	SW U.S., Central America, Philippines, India, Sudar, Florida, Tanzania, Cuba, Jamaica, Hawaii, Puerto Rico, St. Croix	Brazil, Portugal, Zaire, Spain, Mexico, Senegal, Ethiopia, El Salvador, Jamaica, Argentina, Venezuela	Arid zones of Northern Argentina, Paraguay, Bolivia
Latitudinal range		Tropics	Tropics/subtropics	Humid tropics	
Environmental requirements					
Soil	Deep, well-drained, rich soils; tolerates soils with laterite and limestone	Wide range of deep or shallow soils; pH 3.0 to 9.5	On most soil types: clay, colitic limestone, barren sands, wet sands with brackish water table	Well-drained soils; not selective but wet soils stunt its growth	Sands with high clay; tolerates some salt
Temperature	Cannot withstand cold but thrives in tropical heat	Humid tropics; 26 to over 30°C	Warm tropical and subtropical	Cool subtropical but can grow in warm/dry areas	Not frosty hardy; 15°C - mean temp.
Altitude	Lowland	Up to about 600 m	Mexico: Up to 1,800 m Burundi: Up to 1,500 m	2,400 m	100-500 mm; resistant to drought
Rainfall/moisture	Most prevalent in monsoonal areas with 1,000 mm or more and with 4-5 months dry season	1,500-1,800 mm with 6 months dry season	450-1,650 mm/yr; resistant to drought		
Environmental impacts					
On soil erosion		Roots can hold soil in place; used to stabilize slopes in Indonesia			Windbreaker

On soil moisture and water table		Soil cover crop and shade tree to maintain soil moisture			
On soil nutrients				Nitrogen-rich leaves for humus	Nitrogen fixer
On undergrowth			Shades out more desirable forage plants		
Economic uses					
Mainstem and branches	Firewood, timber for cabinet-making	Fuelwood, wood pulp, charcoal	Firewood; general construction purposes; posts	Firewood, pulp for paper	Firewood, wood for flooring, wine casks, shoe-lasts, and paving blocks
Fruits and seeds			Pods for food and drinks, for fodder, seeds with oil for food and soap-making		Pods for cattle; milled seeds for human food
Leaves			Fodder		
Other	Host for sandalwood	Bark contains 13% water soluble tannin; shade tree	Shade, hedges, ornamental, bark extract for tanning, gum from bark, shelterbelt, flowers for honey	Fertilizer; ornamental, fence	Windbreak and roadside planting
Productivity					
Wood yield	Up to 15 m^3/ha	Indonesia: 17-20 m^3/ha/yr Malaysia: "	Can reach a height of 10 m in 5-6 years	14 mos.: 5 m tall 2 yrs.: 8-9 m tall 3 yrs.: Up to 15 m	In Argentina: 10 years old plantations give 7 m^3/ha/yr spaced 2 x 2 m on a fair site
Nitrogen yield					
Management					
Establishment, spacing, timing	Direct seeding, seeds require no treatment if they are fresh; old seeds must be scarified with hot water or sulfuric acid	Direct seeding and nursery-raised seedlings	Cuttings or seeds	Direct seeding at 3-4 seeds in shallow depression (3-4 cm) at distances of 2-3 m apart	Direct seeding but seedling transplanting is better at 2 x 2 x 4U cm when seedlings are 2-3 months old; plant in spring or the onset of rainy season
Tending care	Weeding in the first year or so; protect from browsing livestock or wildlife	Weeding during early years; treat seeds with boiling water and soak for 24 hours			Inoculate seeds with mesquite rhizobia
Pest and disease	Susceptible to attack by scale insects	Zanzibar: Seedlings attacked by insects and nematodes	Leaf spot disease; host for thornbug; dofoliating and boring insect nests		Bruchid beetles attack seeds in pods
Harvesting	Yields for 4 or 5 rotations; every 7 yrs. harvesting.				
Regeneration	Coppices readily	Coppices poorly; regeneration thru seedlings	Coppices vigorously		

Table 1 (cont.)

Items	*Leucaena leucocephala*	*Prosopis chilensis*	*Sesbania bispinosa*	*Sesbania grandiflora*	*Albizia lebbek*
Species identification					
Scientific name	*Leucaena leucocephala*	*Prosopis chilensis*	*Sesbania bispinosa*	*Sesbania grandiflora*	*Albizia lebbek*
Synonym	*Leucaena glauca*		*Sesbania aculeata*	*Agati grandiflora*	*Mimosa lebbek*, *mimosa sirissa*
Common name	Leucaena, ipil-ipil, lamtora, guaje, yaje, auxin, leadtree	Algarroba, kiawe, mesquite, algarrobo blanco, algarrobo de Chile	Dahaincha, prickly sesban	Agati, bacule, katurai, turi, gallito, chogache, August flower	Lebbek, karana, kokko, frywood
Distribution					
Country(ies) of origin	Midlands of South Mexico, Guatemala, Honduras, El Salvador	Peru, Chile, Eastern Argentina	Tropical/subtropical areas of the Indian subcontinent	India, Malaysia, Indonesia, Philippines	India, Pakistan, Bangladesh, Burma
Current geographic location	Mexico, Pac, Islands, Indonesia, Papua New Guinea, Malaysia, East and West Africa, South America, Philippines	South America, Hawaii	Tropical Africa, Southeast Asia, China, West Indies	Asia, West Indies, Central and South America, Mauritus	India, Bangladesh, Pakistan, tropical/subtropical North Africa, West Indies, South America, Southeast Asia
Latitudinal range	Tropics/subtropics		Tropics/subtropics	Tropics/subtropics	Tropics/subtropics
Environmental requirements					
Soil	Grows well in neutral or alkaline soils; sandy clay to sandy loam; does not like acidic soils		Grows on saline and alkaline wastelands and wet, almost waterlogged soils	Wide range including black, poorly structured clay	Moist, well-drained loam; tolerates sea sprays
Temperature	Tropical/subtropical; frost kills it	Withstands high desert temp.; requires 27°C	Tropical/subtropical	Tropical conditions; frost sensitive	Tolerates light frost and drought after first year
Altitude	Below 500 m	Peru: Up to 2,900 m India: 340-1,230 m	Up to 1,200 m	Up to 800 m	India: Sea level to 1,600 m
Rainfall/moisture	600-1,700 mm 400-800 mm (Philippines)	200-400 mm/year; very resistant to drought	550-1,100 mm; resistant to drought	More than 1,000 mm with a few months of dry season	500-2,000 mm with wet summers
Environmental impacts					
On soil erosion	Suppresses undergrowth in the first 3-4 years		For erosion control	Used to reforest eroded land	Good soil binder
On soil moisture and water table	Roots break subsoils improving soil penetration				

On soil nutrients	Nitrogen fixer; nitrogen from foliage	Probably N-fixer	Fertilizer from nodules and leaves	Nutrients for litterfall and nitrogen fixation	Nitrogen fixer
On undergrowth	Shade out undergrowth during the first 3-4 years				
Economic uses					
Mainstem and branches	Firewood/charcoal, lumber/timber, pulp and paper, roundwood, construction material, fence posts, banana props, direct fuel source for steam-powered generators	Firewood; wood is easy to work finishing smoothly and taking a natural	Firewood; pulp and paper; cordage fiber for fishing nets, gunny sacks, and sail	Firewood, pulp and paper, roundwood, gum from bark, tanning agent from bark	Fuelwood, wood for furniture and houses; carves and polishes well
Fruits and seeds	Pods for food; seeds for beverage, medicine		Gum for textile and paper products	Pods for fodder, human food	Fodder
Leaves	Fodder, N-source	Pods are excellent food	Fodder for cattle; green manure	Vegetables, fodder, green manure	20% protein when young; green manure
Other	Shade and ornamental, windbreak, tannin from barks	Fodder	Windbreak, shade, hedge, cover crop	Ornamental, shade, windbreak, fence	Shade, nectar for honey; ornamental
Productivity					
Wood yield	30-40 m^3/ha/yr (mean) Philippines: 24-312 m^3/ha/yr		15 bone-dry t/ha/yr or more where more than one crop/yr can be harvested	20-25 m^3/ha/yr	In 10-15 years rotation: 5 m^3/ha/yr
Nitrogen yield	Leaves contain 0.5-1% of the green weight or 4.3% of the dry weight in N				
Management					
Establishment, spacing, timing	Seeds in hot water, then soak 2-3 days; direct seeding or by seedlings; plant at the start of rainy season at 2 x 2 m or 2 x 3 m for bigger wood yield	Propagated by seeds; seeds must be scarified in hot water or sulfuric acid before planting	Establishes easily by direct seeding; no seed treatment required	Propagates easily by cuttings or seedlings; no seed treatment required	Direct seeding; also stem or root shoot cuttings; boil seeds and soak for 24 hours
Tending care	Weed control, inoculate soil, keep soil moist		Can compete with weeds	Requires little maintenance	Weeding during the first 2 years
Pest and disease control	Use semesan, ceresan, ferbam, arasan for seeds; damping off and fungal diseases	Bruchid beetles destroy seeds		Susceptible to nematodes; also damaged by birds and grasshoppers	Protect from browsers; in India, some fungus attack the leaves and pods
Harvesting	For fuelwood, cut when 4-6 years old		Two harvests a year	3-4 years, although 2 years is okay	10-15 years rotation
Regeneration	Coppices well		Two harvests a year are possible	Coppices	Coppices fairly well

Table 1 (cont.)

Items	Gliricidia sepium	Calliandra calothyrsus	Acacia mearnsii	Acacia senegal	Acacia seyal
Species identification					
Scientific name	Gliricidia sepium	Calliandra calothyrsus	Acacia mearnsii	Acacia senegal	Acacia seyal
Synonym	Gliricidia maculata	Calliandra confusa	Acacia mollissima	Acacia verek	Acacia fistula
Common name	Madre de cacao, mata-raton, kakauati	Calliandra	Black or tan wattle	Gum acacia, hashab, gum arabic tree	Talh, shittim wood
Distribution					
Country(ies) of origin	Mexico, Central America, Northern South America	Central America	Victoria, S. Australia, New South Wales, Queensland, Tasmania	Southern Sahara, Sahelian zone from Senegal to Somalia, Sudan	Africa
Current geographic location	Mexico, C. America, S. America (Brazil), West Indies, Asia, Southern Florida	C. America, Indonesia	New Zealand, S., C. and E. Africa, India, Sri Lanka, parts of C. America, Indonesia	Sudan, Senegal, India, Pakistan, Nigeria	Africa, Egypt
Latitudinal range	Humid tropics	Humid tropics	Tropical highlands		
Environmental requirements					
Soil	Does well in moist or dry soils, even with limestone	Can grow on infertile and heavy compacted clay with poor aeration	Cannot tolerate calcareous soil; can grow on poor soils	Grows in sand, clay except where rainfall is high (800+ mm/yr) which will cause waterlogging	Often found on stony ground; grows on most soil types even heavy clay
Temperature	22-30°C		Cool winters; slow growth on high temp.; frost tolerant	Sudan: 14-43°C India: (-4 to 48°C)	Hot
Altitude	Up to 1,600 m but mainly below 500 m	150-1,500 m	Australia: Up to 1,100 m Indonesia: Up to 110 m Natal and South America: 300-1,100 m	100-1,700 m	Tropics: Up to 2,100 m; a lowland tree
Rainfall/moisture	1,500-2,300 mm or more	Over 1,000 mm but can withstand drought for several months	500-700 mm	Range: 200-800 mm Opt.: 300-400 mm; resistant to drought	Drought tolerant; 350+ mm/year
Environmental impacts					
On soil erosion	Conserves ground water	Soil binder on slopes	Good on hillsides of up to 50-degree slope	Ideal for reclamation of refractory sites and sand dunes and wind erosion control	
On soil moisture and water table	Conserves ground water when it drops its heavy mantle of leaves	Provides ground cover to reduce evapotranspiration rate			

On soil nutrients	Nitrogen fixer	Ground cover improves soil; nitrogen fixer	Green manure	Nitrogen fixer	
On undergrowth		Chemicals from litterfall	Nitrogen fixer		
Economic uses					
Mainstem and branches	Fuelwood, wood for furniture, small articles, agricultural implements, tool handles, posts and heavy construction	Firewood	Fuelwood, roundwood, tannin from bark for leather products, pulpwood for wrapping paper	Fuelwood, charcoal, poles, agricultural implements	Firewood, lumber
Fruits and seeds	Flowers for bees			Pods for fodder; dried seeds for food	Pods and flower for fodder
Leaves	Green manure or ruminant feed	Fodder (7-10 t dry fodder/ha/yr)	Green manure	Feeds for camels, sheeps and goats	Fodder
Other	Fence, windbreak, shade, ornamental	Ornamental, firebreak, nectar for honey	Forage	Roots for ropes/nets; gum arabic source	Edible gum when fresh
Productivity					
Wood yield	8 m^3/ha/yr	After first year: 5-20 m^3/ha/yr; after second year: 35-65 m^3/ha/yr	10-25 m /ha/yr	5 m^3/ha/yr (dense); 0.5-1 m^3/ha/yr (sparse)	Slow growing
Nitrogen yield			21-28 t wet leaves; with 240-285 kg N		
Management					
Establishment, spacing, timing	Seeds or cuttings; seeds in hot water and soak overnight before planting	Seeds or seedlings for plantations; planting should be done at the start of the wet season; transplant 4-6 mos. old seedlings at 1 x 1 m or 2 x 2 m	Direct seeding; dormancy of seeds is broken by immersing them in boiling water	From seeds; overnight soaking of seeds is effective	From seeds, large cuttings; nick or boil seeds briefly
Tending care		Treat seeds with hot water and soak for 24 hours		Weeding for first 2 years; protect from browsers	
Pest and disease	Termite resistant; aphids attack foliage which leaves to fall		Not serious but susceptible to attack under wet conditions with more than 3,000 mm rainfall/year	Pods: Insects Roots: Termites Seedlings-susceptible; mature-resistant	Resistant; felled logs may be severely damaged by wood borers
Harvesting		Can be harvested annually	7-10 years		
Regeneration	Coppices easily	Coppices readily	Coppices poorly	Coppices well	

SOURCES: "Firewood Crops" (NAS); "Tropical Legumes" (NAS).

Table 2. Ratings of Uses and Environmental Adaptability of Some Nitrogen-Fixing Legume Trees

Uses	Acacia auriculiformis	Acacia mangium	Albizia falcataria	Albizia lebbek	Calliandra calothyrsus	Dalbergia sisso	Gliricidia sepium	Leucaena diversifolia	Leucaena leucocephala	Samanea saman	Sesbania grandiflora
Human food	C*	C	C	C	C	C	B	C	A	B	A
Fuelwood	A	B	C	A	A	A	A	A	A	B	A
Poles	C	B	C	A	C	B	A	A	A	C	A
Sawnwood	C	A	A	B	C	A	C	C	C	A	C
Pulpwood	A	A	A	C	B	B	C	A	A	C	C
Woodcraft	C	B	C	A	C	A	B	B	B	A	C
Forage	C	C	C	A	B	B	A	A	A	B	A
Green manure	C	C	B	A	A	B	A	A	A	C	A
Environmental adaptability											
Acid soils	A	A	-	-	B	-	-	C	C	-	C
Drought	B	B	C	B	B	A	B	A	A	A	B
Coppicing ability	A	A	A	A	A	A	A	A	A	A	A
Minimum rain (mm/yr)	750	750	1,500	600	1,000	500	1,500	600	600	600	1,000

*Ratings:
A = Good
B = Fair
C = Poor

SOURCE: Brewbaker, J., R. Van Den Beldt, and K. MacDicken, 1981.

Table 3. Properties of Some Nitrogen-Fixing Legume Trees

Properties	Acacia auriculiformis	Acacia mangium	Albizia falcataria	Albizia lebbek	Calliandra calothyrsus	Gliricidia sepium	Leucaena diversifolia	Leucaena leucocephala	Samanea saman	Sesbania grandiflora
Specific gravity	0.68	0.65	0.33	0.58	0.65	0.75	0.55	0.54	0.52	0.42
Wood yield (cm/ha/yr)	15	30	40	5	50	8	25	45	15	22
Average height growth (m/yr)	2.6	2.5	5.0	1.4	6.0	2.5	4.0	4.5	2.5	3.3
Height at maturity (m)	30	30	45	30	10	10	20	20	45	10
Diameter at maturity (cm)	60	25	100	20	50	20	30	35	180	30

NOTE: The above growth figures are from trials in Hawaii and may be used as indicators only. Growth rates in other sites could vary widely from them.

SOURCE: Brewbaker, J., R. Van Den Beldt, and K. MacDicken, 1981.

APPENDIX

SIMPLE FIELD METHODS TO DETERMINE OR ASSESS SOIL ACIDITY OR ALKALINITY

A soil sample, thoroughly mixed with an equal volume of distilled or rain water, can be tested for acidity or alkalinity by any of the simple methods described here:

Litmus paper—These are strips of chemically-sensitive paper that are white, blue, or red. The blue paper turns red in the presence of acid and remains blue if the solution is alkaline. The red paper turns blue if the soil solution is alkaline and remains red if acidic. The white paper turns either red or blue depending on whether the soil solution is acidic or alkaline. Litmus paper is usually sold in small vials containing 100 strips. It is available from laboratory chemical supply companies.

Other pH indicating papers—These come in various brand names: "Hydrion," Fisher "Alkacid," and Squibb's "Nitrazine." They indicate pH on the same principle as the litmus paper. When in contact with soil solutions they turn to certain colors that correspond to a given pH on a color chart. They are usually sold rolled in a dispenser together with a color chart. For field technicians this is the most convenient and dependable pH kit to use.

pH indicating liquids—These are solutions of various chemicals which produce a certain color upon reacting with the soil solution, and pH is read on a color chart just like with the pH paper. Persons who do soil survey work prefer to use this kit.

Kitchen methods--Soils that have high calcium carbonate (hence, alkaline) can be easily detected by wetting the soil with a few drops of a weak solution of muriatic acid, vinegar, or lime juice. The presence of the mineral can be confirmed by the appearance of bubbles as a result of its reaction with the acid.

Inference method--Persons with experience in soil survey and classification can make a good guess of the alkaline or acid condition of certain soils. Yellow or red soils are generally acid due to the abundance of iron and aluminum compounds. Black or dark brown soils with heavy clay texture are generally neutral to alkaline. Poorly drained soils that are subject to rapid drying in some months of the year are generally alkaline because of the accumulation of salts.

Electronic methods--These are portable electronic instruments called pH meters. Unless one is engaged in scientific research these instruments are not recommended for routine field use. These instruments are expensive and require technical skills and knowledge to operate them.

NEW DIRECTIONS IN AGROFORESTRY: THE POTENTIAL OF TROPICAL LEGUME TREES

INITIAL TASKS IN AGROFORESTRY PROJECTS

Edited by
Napoleon T. Vergara

Prepared by a
Working Group on Agroforestry
Environment and Policy Institute
East-West Center
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June 1982

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NEW DIRECTIONS IN AGROFORESTRY: THE POTENTIAL OF TROPICAL LEGUME TREES

Initial Tasks in Agroforestry Projects

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Socioeconomic Surveys 1

Survey of Local Demand 2

Inventory of Available Local Resources 3

Survey of Existing Production Systems as Possible Bases for Agroforestry 5

Motivating Local People to Participate in Agroforestry 5

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In some countries, the value of agroforestry as an effective tool for reaching ecological as well as economic development goals has been well recognized. Policymakers have adopted agroforestry as a desirable system of land use in upland areas and steps have been taken to promote and implement agroforestry systems among upland farmers. Before an agroforestry project is planned or implemented, however, certain preproject tasks need to be undertaken.

SOCIOECONOMIC SURVEYS

It is essential that the existing social and economic system is first surveyed to obtain background information that will allow the program planners to identify the needs of the target farmers as well as the key constraints. By responding to expressed needs, a program will have a better chance at adoption. The proposed program must be technically feasible, economically attractive, and socially acceptable if it is to be adopted by farmers.

The required surveys can be carried out by extension officers or other staff and should be designed to measure the particular conditions in any given area. Besides identifying the presently available levels of land, manpower, and capital resources, the surveys provide a baseline measurement of the preproject situation. If a project is implemented, the postproject conditions can then be compared to the earlier situation to determine the extent of economic or social benefits from the project.

Survey of Local Demand

Food, Fuelwood, Fodder, and Fertilizer. One of the first steps in agroforestry project planning is the assessment of the current demand for and supply of food, fuelwood, fodder, and fertilizer in the project area. This survey will determine the main sources of supply and the type of demand for these products. By identifying the amount of time and resources spent on supplying any of these products, the possible contributions of agroforestry products can be identified. Demand can come from the farmer and his family, from other families, or from a local market.

In determining the relative demand for and supply of various goods in the project area, the researcher, who may be a local extension officer or someone from outside the study area, may consult agricultural research institutes, local statistical offices, other government agencies, and the local market. A better approach, however, is to obtain data directly from the farmers themselves through personal interviews of randomly selected respondents. The researcher can obtain the desired information through the use of a prepared questionnaire. By using systematic sampling techniques, the researcher can collect reliable information without having to interview all the farmers in the community.

A sample survey is not presented here. The designing, pretesting, and conducting of a complete socioeconomic survey is a specialized task. When a survey is required, assistance should be sought from a suitable source such as the local statistical office, a university, or a government survey office. Many different survey forms already exist, but any general form will have to be evaluated and perhaps modified before it is pretested.

For an agroforestry project appraisal a survey might consider the supply of and demand for food or fuelwood or fodder or organic fertilizer. If the survey reveals that a shortage exists or that unduly large amounts of resources are used to obtain one good, this may indicate a potential role for agroforestry production. For example, if collecting firewood or fodder requires many person days each month, a fast-growing tree that is a good firewood or fodder producer may be useful. On the other hand, if fuel and fodder are not problems but low crop yields are, a tree variety that produces large amounts of green manure may be called for. By identifying key problem areas or urgent needs, the planner can devise projects that will have a better chance of adoption and success.

Inventory of Available Local Resources

An inventory of local resources such as land, labor, and capital is a way of determining present resource availability and utilization at the village or project level. When a specific locale is considered for an agroforestry project, whether it is an individual piece of land or a wider area, the development worker should collect as much available information as possible about the area. Several factors that must be assessed clearly are discussed here.

Total Land Area Available for Production. The aggregate land resource available in the project area and land resources per household should be determined. Land distribution and tenure relationships are important.

Land Required for Subsistence. This refers to the minimum land area required for subsistence production. The subsistence equivalent can be calculated for a specific location, crop mix, and dietary preference. This area can then be compared to the available land resources to determine if a land constraint to agroforestry development exists. Of course, land required for subsistence production is a function of the level of productivity as well as institutional factors.

Labor Employment. Based on farm calendars constructed from farmer interviews, labor availability by period can be determined. The peak and slack labor periods can then be coordinated with the labor requirements of a proposed agroforestry project. The opportunity cost of labor also needs to be examined. Off farm employment may be substantial and could be a major source of cash income.

Competition for Capital. The availability of capital to implement the proposed agroforestry project and the willingness of farmers to commit these resources will have to be examined. If local capital is insufficient, government may need to provide support in the form of grants, aid, or credit.

Development workers can inventory local resources by consulting local officials and other government agencies and by interviewing the farmers themselves through questionnaires.

Survey of Existing Production Systems as Possible Bases for Agroforestry

In addition to an inventory of locally available resources, detailed information on existing production systems is needed. This information can be obtained by survey techniques; the survey will identify the different farming systems used prior to the introduction of agroforestry. These systems should be analyzed in order to understand why they have been used continuously by the local farmers, and to determine whether there are features in common with agroforestry that may make adoption easier. A questionnaire that will aid in gathering information about the current practices of food and tree production should be developed and farmers interviewed. Field visits will also be useful.

Knowing the good points or benefits of the existing production systems is important in the development of an agroforestry system suited to a specific site and group of people. A proposed agroforestry project should integrate existing beneficial farming practices into the new system. In this way the farmers feel some continuity of cultural practices as well as acceptance of part of their traditional approach.

MOTIVATING LOCAL PEOPLE TO PARTICIPATE IN AGROFORESTRY

Rural development projects formulated by central government planners to improve the social and economic status of people in the countryside are often not successful. One important reason for failure is a lack of cooperation and support from the same people the development programs are supposed to benefit. This lack of interest and cooperation on the part of local inhabitants sometimes stems from their being taken for granted and not being given opportunities to participate in the planning of the project, although they may later be invited or even forced to participate in the implementation. This is particularly the case with female farmers who frequently produce much of the food and fuelwood consumed in the tropics.

Phases Where Local Participation is Important

Successfully introducing agroforestry systems to an upland community requires involvement and participation of that community in all phases of the project. Farmers—both male and female—should be involved in several ways.

Problem Identification. Farmers can list the problems commonly faced by the people in the upland community. Such problems include rapid hillside erosion that causes declines in food output, excessive forest cutting that has resulted in fuelwood shortages, or lack of wood for on-farm use.

When preidentified problems become the focus of the project, the people are more likely to recognize that the project is for their benefit and they may participate more enthusiastically.

Goal Setting. Goals can be set as targets and, if the project can meet these goals, farmer support for the project will increase. Examples of goals are the provision of so many kg of fuelwood or fodder per year from fast growing trees, a certain increase in staple food yield, or some measure of erosion control.

Identifying Alternative Solutions to The Problem. Once a problem has been identified and goals set, alternative solutions to the problem can be proposed. For example, possible solutions to an upland erosion problem include:

- terracing to stabilize the soil
- applying fertilizers to replace nutrients lost through erosion
- interplanting trees with food crops to stabilize soils and provide organic fertilizer

One important advantage of this process is that farmers are usually more familiar with possible alternatives than an outsider would be. Farmers know what can work, what is feasible, and can suggest an array of practical and site-adapted solutions.

Identifying The Most Suitable Alternative. There are various ways of judging alternatives. Some are based on straight economic analysis while other ways incorporate more social or cultural values. Farmers may add practical methods or criteria for project selection. These criteria may include such things as choosing the alternative that results in highest food yields per hectare per year, uses the least labor (and maximizes leisure), demands the smallest cash outlay, involves a "once-only" action rather than a recurrent series of actions or work, or solves one or more problems simultaneously (e.g., fodder and fuelwood shortages). The inclusion of these criteria may result in selection of an alternative solution different from one based on economic analysis alone.

Implementing The Selected Project. Since the farmers themselves are involved in selecting the solution to the problem from among several alternatives, they should be more enthusiastic about participating in project implementation.

Monitoring. As implementation progresses, monitoring of results is necessary to determine whether the set goals are being achieved or are likely to be reached. If not, modifications can be made, and with the farmers' understanding and participation in the process, these changes may be both effective and more readily accepted.

Mobilization of Local Communities

Members of the local community should be involved in development projects such as agroforestry. When individual contact is not possible because of the limited resources of extension agencies, another approach is to reach the formal (elected) as well as the nonformal (traditional) community leaders, and, through them, reach others. Because of their position in the community and their familiarity with the local population, these leaders usually have greater credibility with and influence over their people compared to an outsider like a newly assigned extension worker.

One approach is for the extension agent to gain the cooperation and support of local leaders by involving them in the phases of development planning as outlined earlier, including the implementation phase. Once that stage of rapport and cooperation is reached, the leaders could assist in spreading favorable information about the project among their community in two ways:

1. By acting as spokespeople in favor of the project. Their deep involvement in the planning phase gives them a level of understanding that would make them effective and convincing advocates of the project.
2. By demonstration. During the implementation stage the local leaders can develop their individual projects to serve as demonstration plots. If the plots are successful, that is, if the goals are achieved or the problems solved, other members of the community may be more inclined to support the implementation of the project, and eventually the entire community would be involved.

In addition, groups other than established community leaders may be approached. If these frequently ignored groups—such as women, landless labor, and ethnic minorities—are involved and helped, they may prove to be enthusiastic and dedicated workers.

APPENDIX D3

NEW DIRECTIONS IN AGROFORESTRY: THE POTENTIAL OF TROPICAL LEGUME TREES

SUSTAINED OUTPUTS FROM LEGUME-TREE-BASED AGROFORESTRY SYSTEMS

Edited by

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NEW DIRECTIONS IN AGROFORESTRY: THE POTENTIAL OF TROPICAL LEGUME TREES

Sustained Outputs from Legume-Tree-Based Agroforestry Systems

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As an integrated cropping system, agroforestry is expected to produce, on a continuing basis, a mix of outputs not normally found in intensive monoculture or single-crop systems. These products may be classified roughly into two groups: food products (including fodder) yielded by both the agricultural crops and tree crops; and wood products extracted from the trees.

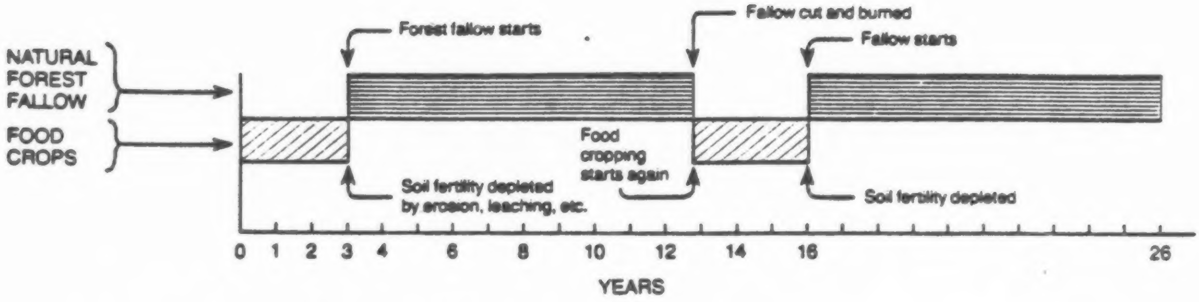
Legume-tree-based agroforestry normally yields greater sustained outputs per hectare per year compared with agroforestry with ordinary trees. The primary reason for this yield difference is the nitrogen fertilizer contributed by legume trees. (See "Selection of Legume Trees for Agroforestry.")

Food crops and tree crops are usually integrated in agroforestry on the same unit ot land either in a simultaneous or alternating manner. The system of production for each type of output is discussed separately here for convenience and clarity.

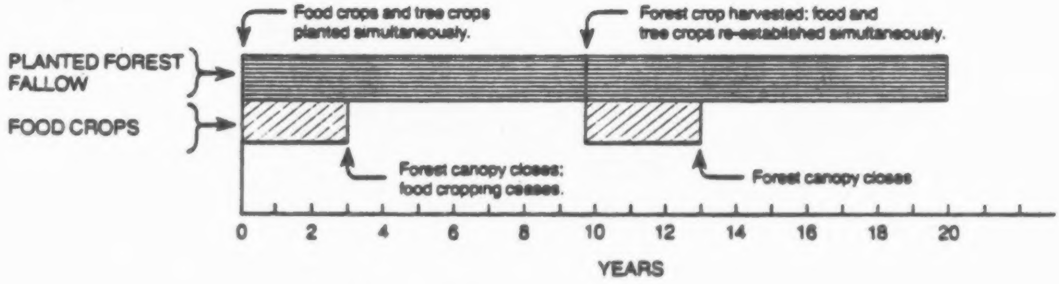
FOOD CROP PRODUCTION IN AGROFORESTRY

In the view of the subsistence-type upland farmer, staple foods for home consumption rather than wood are the most important products of agroforestry farms. These foods consist of cereals (e.g., rice, corn), root crops (e.g., taro, cassava, sweet potato), and pulses (e.g., beans) and are mostly annual rather than perennial food crops.

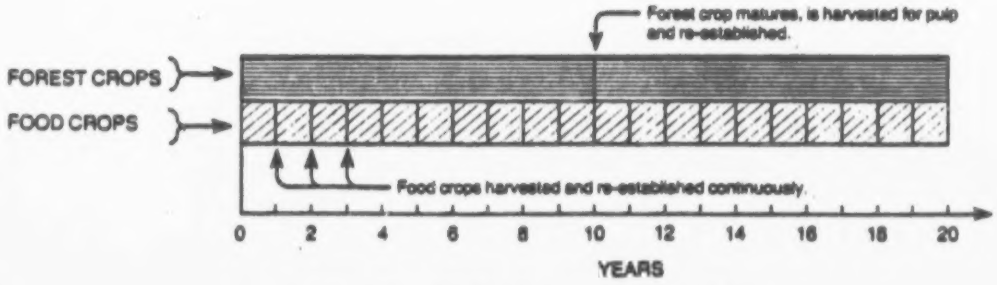
The need for continuous food production and the farmers' inherent desire for permanent land tenure suggest that integral rather than the Taungya or swidden agroforestry system should be employed (Figure 1). In terms of space arrangement, border tree


Forest fallow starts
Fallow cut and burned
Fallow starts
NATURAL FOREST FALLOW
FOOD CROPS
Food cropping starts again
Soil fertility depleted by erosion, leaching, etc.
Soil fertility depleted
0
1
2
3
4
6
8
10
12
14
16
26
YEARS

Cyclical or shifting cultivation system


Food crops and tree crops planted simultaneously.
Forest crop harvested: food and tree crops re-established simultaneously.
PLANTED FOREST FALLOW
FOOD CROPS
Forest canopy closes: food cropping ceases.
Forest canopy closes
0
2
4
6
8
10
12
14
16
18
20
YEARS

Taungya system


Forest crop matures, is harvested for pulp and re-established.
FOREST CROPS
FOOD CROPS
Food crops harvested and re-established continuously.
0
2
4
6
8
10
12
14
16
18
20
YEARS

Integral or simultaneous cropping system

Figure 1. Temporal arrangement of crops in agroforestry.

NOTE: It is assumed that the forest fallow is ready for cutting and burning or for harvesting in 10 years.

planting, alternate row, or alternate strip (or alley cropping) can be used, but either of the last two may be suitable (Figure 2).

Because food production is the major aim of subsistence farmers, more of their farmland is often allocated to food rather than to forest crops. The division of land use between food and tree crops may range from 50:50 percent to as much as 90:10 percent in favor of food crops. Legume trees integrated with food crops help stabilize the soil and supply organic fertilizer, especially nitrogen.

Productivity of Legume-Fertilized Food Crops

It has been clearly demonstrated in research plots that food crops interplanted with nitrogen-fixing legume trees are generally more productive than those planted as a single crop or interplanted with ordinary trees that do not fix nitrogen. It is logical to expect, therefore, that as long as the legume trees do not overcrowd and overshade the food crops, and as long as the trees are appropriately matched with site conditions to enable them to fix sufficient amounts of nitrogen to satisfy the requirements of the food crops, legume-tree-based agroforestry on upland subsistence farms will be more productive.

Nitrogen fixed in root nodules of legume trees reaches and benefits the intercropped plants through natural biological processes. The fixed nitrogen eventually ends up in the leaves, and when these leaves fall on the ground and decompose, nitrogen is released back to the soil and used by the shallow-rooted food

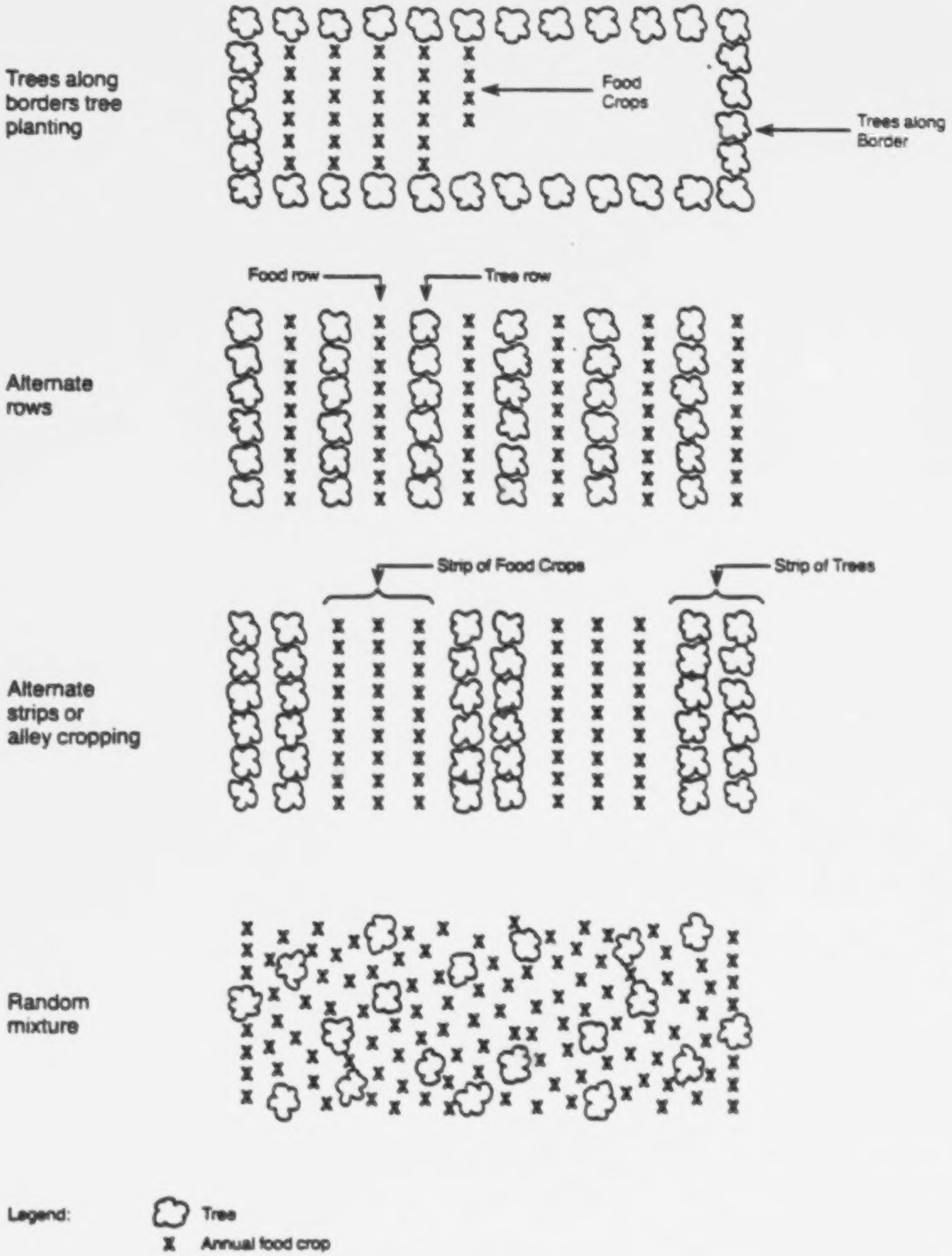

Trees along borders tree planting
Food Crops
Trees along Border
Food row
Tree row
Alternate rows
Strip of Food Crops
Strip of Trees
Alternate strips or alley cropping
Random mixture
Legend:
Tree
Annual food crop

Figure 2. Spatial arrangements of crops in agroforestry.

crops. As much as 60 percent of this recycled nitrogen is lost to the atmosphere through denitrification and leaching, however, leaving only about 40 percent for use by food plants.

Green manuring can be adopted as an alternative approach to natural nitrogen recycling. Instead of waiting for the leaves to fall and decay, the farmer can prune the tree tops and branches at regular intervals, say perhaps every 6 or 8 weeks, and spread them among the food crops as mulch and organic fertilizer. Trials in the Philippines using pure Leucaena plantations, for example, show that pruning every 8 to 12 weeks produces 10 to 24 tons of fresh green manure per ha per year. The nitrogen equivalent has been noted to vary from 70 kg to about 500 kg per hectare per year, depending on the nitrogen-fixing rate of the tree species as influenced by site conditions and the Rhizobia present in the roots.

Leucaena green manure in separate Hawaiian and Philippine experiments showed corn yields increasing by about 100 percent over unmanured control crops. The Philippine study demonstrated that all the nitrogen needs of the corn had apparently been satisfied by the Leucaena intercrop, as suggested by the fact that further additions of 10 kg and 20 kg of commercial nitrogen per hectare, respectively, produced no greater increases in corn yield.

In another trial, on lowland fields, 8 tons of Leucaena leaves per hectare applied to rice variety IR 36 rice crop produced results comparable to application of 69 kg per ha of commercial nitrogen fertilizer; yields increased by 89 percent.

Similar tree-food crop combinations using Leucaena or other legume trees may or may not yield the same outputs, depending on whether the conditions are comparable. Additional trials are needed in other countries using locally available suitable legume trees such as Sesbania and Gliricidia.

Management of Tree-Food Crop Interplanting

Either the alternate row or alternate strip system of crop arrangement is recommended for tree-food crop interplanting to maximize the soil-stabilizing role of the legume trees on upland farms. The strip of trees consisting of two or more rows may be planted at the start of the rainy season as hedges along contour lines or across the slope. If it is decided from the start that the trees are to be used only to stabilize and fertilize the soil and not to yield wood products, they can be spaced 20 cm or less along rows and 1 m or less between rows. A strip 4 m wide or greater between hedgerows is reserved for food crops (Figure 3).

The close tree spacing along the row makes each multiple-row strip an effective "fence" that blocks the downward movement of soil eroded from the cultivated strip directly above it. In about three years, a slope becomes a series of natural terraces with the hedgerows serving as risers (Figure 4). These terraces add further stability to the slope and serve as cheap and effective soil conservation measures.

Because the tree spacing in the hedgerows may be too close for producing fuelwood and definitely too close to produce timber, the most likely tree products that may be harvested

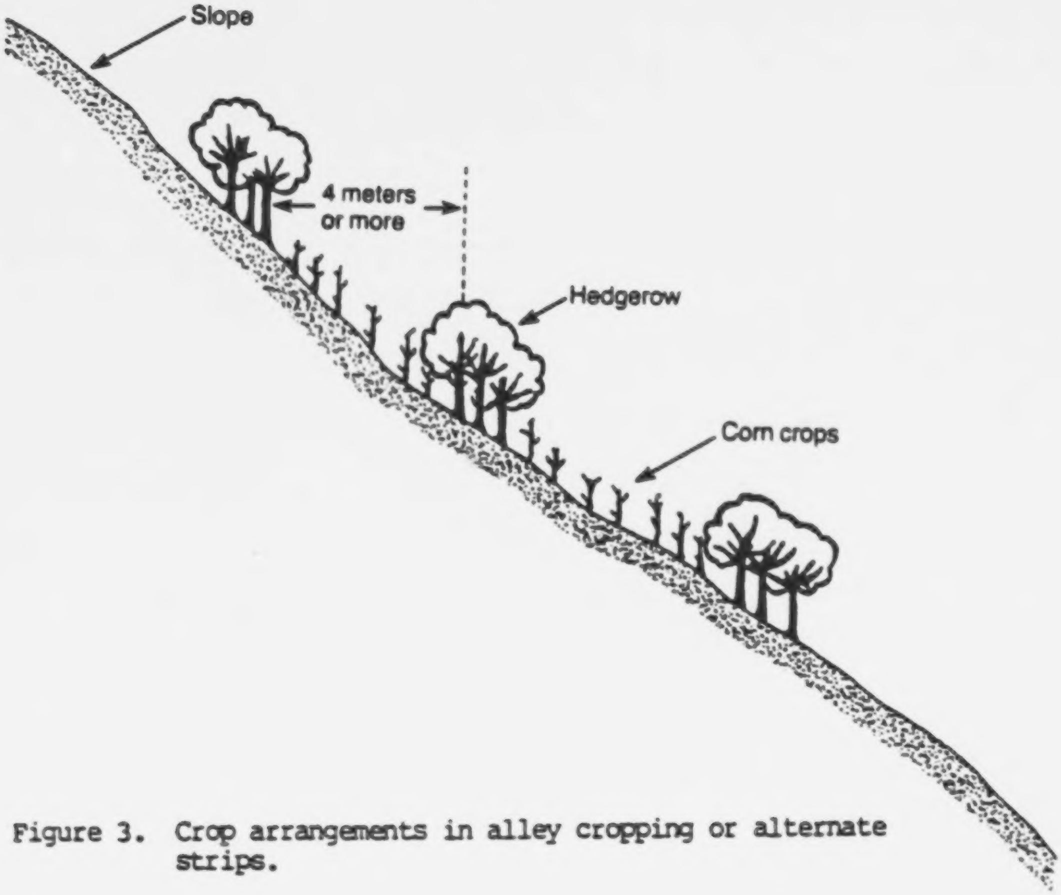

Slope
4 meters or more
Hedgerow
Corn crops

Figure 3. Crop arrangements in alley cropping or alternate strips.

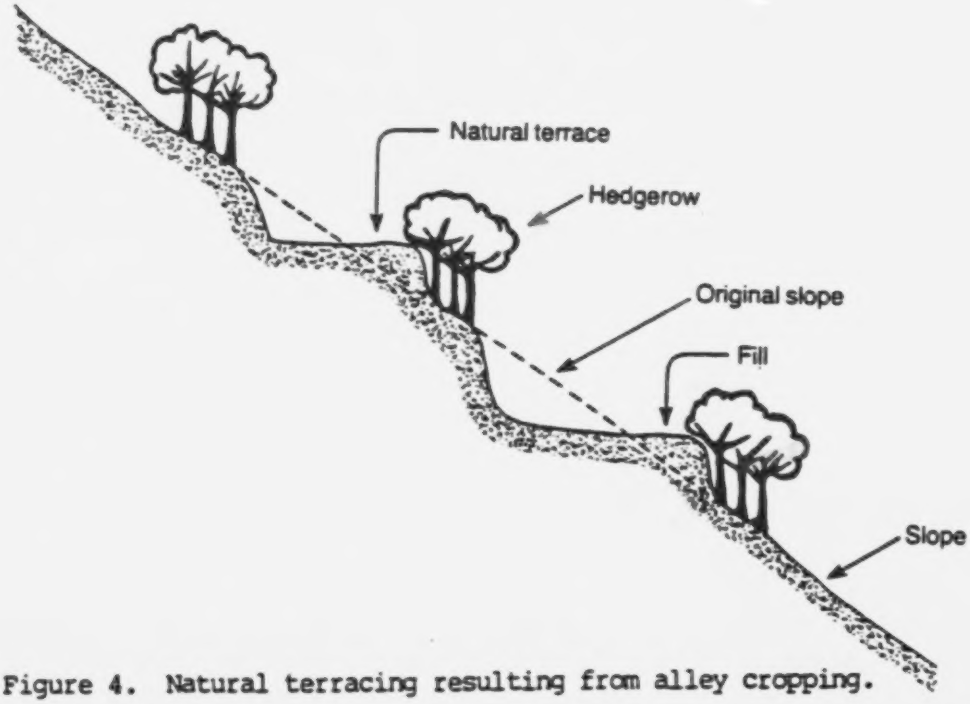

Natural terrace
Hedgerow
Original slope
Fill
Slope

Figure 4. Natural terracing resulting from alley cropping.

regularly are leaves either for fodder or for green manuring. Pruning may start from 3 to 6 months after establishment. The interval of pruning is important: if it is too short, the trees may die since they will not be able to grow enough leaves to manufacture food for themselves through photosynthesis. On the other hand, if the interval is too long, trees may develop into tall, shady hedges that reduce sunlight that can reach the food crops, thereby reducing food yields. In some trials in the Philippines, 2 to 3 months between pruning have been found suitable, but other intervals may be more appropriate under other site conditions using other tree species.

The height of the stumps after cutting is also important. Although the trees survive with as short as 7.5 cm stumps, their herbage yields are greater when the stumps are taller, as shown below for trials of *Leucaena* in pure plantations:

Stump Height	Herbage Yield (dry herbage per ha per year)
15 cm	10.7 tons
150 cm	15.8
300 cm	23.8

Source: Alferez, 1977.

A compromise between yield and convenience is often necessary. For instance, stump heights ranging from 90 to 100 cm will not be as productive as the taller ones, but these waist-level heights make it convenient for the farmers to perform the cutting operations with hand knives or machetes.

Pruning rates for various species may differ because of variations in growth and coppicing abilities. More trials at different sites using different species are necessary to determine optimal pruning rates.

FOOD PRODUCTION FROM LEGUME TREES

The forest component of agroforestry, especially if composed of legume trees, also may serve as a source of protein-rich human food. In Asia, flowers of some species, such as Sesbania and Gliricidia, are eaten as vegetables. Similarly, fruits or pods of others, such as Sesbania, Leucaena, and Parkia, are harvested and consumed as grains or as vegetables for their protein content. It is not surprising, therefore, to find some tree legumes now being cultivated for food among annual crops.

If legume trees are integrated into an agroforestry system and are grown for their food products rather than wood, their stems and branches normally should be left uncut, because pruning tops and branches or harvesting stems may interfere with flowering and fruiting. This means that the trees could become tall, with broad crowns. To prevent them from shading out annual food crops, and at the same time to prevent them from growing too tall for convenient food gathering, they should be planted farther apart—at least 5 m by 5 m depending on the species' inherent growth characteristics. Or they may be planted at 5 m intervals along the borders of fields, leaving the central part of the field open for food crops.

Because nitrogen and organic matter from decomposing fallen leaves may be found only within the reach of the tree crown systems, and since the nitrogen in the root nodules is not usually available directly to the food crops as long as the trees are living, wide spacing of the trees will make little or no nitrogen available to the annual crops located far from the trees unless herbage is deliberately cut and carried to them. Thus, food yields from the annual crops may be lower than when tree spacing is closer and more regular, as in an alternate row or alternate strip arrangement.

Different tree spacings are used when legume trees are planted as a direct food source as opposed to when they are interplanted primarily as a source of nitrogen for annual food crops. When a farmer is deciding whether or not to grow legume trees in an agroforestry system primarily for food and only secondarily for fertilizer, a comparison should be made between the value of food yielded directly by the trees using one spacing and the value of increased annual food crop production using another spacing. In the former system, legume trees are valued for their production of seeds and fruits; in the latter system, the trees are valued for their nitrogen contribution to annual crop production. Depending on quantities produced and prices, one system may be economically more attractive than the other.

It is possible that farmers may never want to raise legume trees in agroforestry systems solely for their food products. They may grow and integrate them for their soil stabilizing and fertilizing role and for their wood products and regard food yields in whatever quantity merely as a bonus. If this is the case, they will grow and space them accordingly and then harvest, lop off, or prune them in accordance with schedules dictated by the more important end products.

FODDER PRODUCTION FROM LEGUME TREES

Leaves of many legume trees, such as Leucaena, Calliandra, Gliricidia, and Sesbania, are palatable to livestock. Because of high protein content (from 15 to 25 percent), legume tree leaves make good fodder or supplements to other feeds. Thus, legume trees in agroforestry systems could be used to produce fodder. Care must be taken, however, to establish tree species that are compatible with both the livestock and the site. One tree species, Leucaena leucocephala, contains a toxic substance called mimosine, which causes animal health problems (such as falling hair) in Australia. However, similar problems have not been reported in Asia.

Fodder may be produced from legume trees in two possible ways: (1) by cutting off the branches and leaves and feeding them to animals located elsewhere; and (2) by allowing the animals to graze directly among the trees. Because the trees are integrated into an agroforestry system, and the interplanted agricultural crops could be damaged by grazing animals, the first system, cut-and-carry, would seem more suitable to agroforestry fodder production.

On the other hand, where short-duration crops, such as upland rice or corn, are interplanted with fodder-yielding legume trees, it may be possible to allow animals to graze in the field periodically, perhaps immediately after the cereal crop is harvested and prior to planting the succeeding food crop. Three advantages of this system are: (1) the animals may feed on the cereal stalks as well as on the tree legumes, thus increasing the amount of forage available per hectare; (2) the labor of cutting and carrying the fodder to the animal pens is eliminated; and (3) the manure produced by the grazing animals is recycled directly into the field.

Legume trees raised principally for fodder in agroforestry systems will at the same time stabilize and, to some degree, fertilize the soil to the benefit of the food crops. They will not produce fuelwood, however, because, as in the case of green manuring, the tops and branches are pruned regularly and used as feed on site or carried to the penned animals. This frequent cutting demands that the tree species chosen must sprout, or coppice, rapidly and profusely. Legume-tree species such as Leucaena and Gliricidia, the leaves of which are palatable to livestock, have this coppicing capability.

When lopping off the branches and tops, as in the case of producing green manure, stumps must be left at heights that are convenient for farmers to cut or easy for animals to graze on the coppices. In general, from 30 cm to waist-high stumps are adequate, although as pointed out earlier, the higher the stump, the greater the fodder yield. The highest yield comes from trees where, instead of pruning, the leaves are simply plucked from the twigs. The added labor needs for this slow process must be balanced against the added yield when deciding what methods of forage-harvesting is used.

If the trees are pruned for forage at appropriate intervals (see green manuring, page 5), a few trees may need to be left uncut, perhaps 10 to 15 per hectare, as shade trees for the livestock. This is especially important to prevent livestock dehydration in hot regions.

The most complex agroforestry combination is one that carries all three components: food crops, trees, and animals, as described above. The most usual forms consist only of two components, however, such as a crop-tree combination or a livestock-tree combination. Thus, a farmer may sometimes grow legume trees alone for fodder with no food crops interplanted. In this case, the animals may graze directly on the sprouts at the tree stumps. Tree spacing in this case would depend on the need for animals to move about rather than on the fertilizer and shade needs of food crops. Spacing between trees could be wider, 5 to 10 m, with from 100 to 400 trees per hectare. An advantage of wide spacing is the possible additional forage from grass growing among the trees.

In another combination of products, livestock and timber can be produced simultaneously if the trees are left unpruned and are spaced widely enough to allow sufficient amounts of grass to grow on the forest floor to fill forage needs. With this system, however, the high-protein legume tree foliage no longer serves as forage. Only the grasses growing under the trees and fertilized by nitrogen-rich litter from the legumes, will feed the livestock.

FUELWOOD PRODUCTION FOR DOMESTIC USE

Next to food, fuel is extremely important to the upland farmer for cooking, heating, and lighting. The most readily available, the cheapest, and most familiar fuel on the farm is wood. In some upland areas, other forms of fuel are either unavailable or too expensive, and fuelwood may be the only source of energy that the farmer can depend upon. A typical Asian farm family of seven members uses 3 to 5 m^3 of wood per year for cooking alone.

Fuelwood for farm use is usually obtained from forested areas. In many cases, however, the forest has receded so that the time and effort needed to find, cut, and carry home fuelwood from distant sources have become excessive. In desperate search of fuel substitutes, some farmers have cut down fruit trees and used dried cattle dung. Action is needed to remedy this deepening rural energy crisis and to make upland farmers and their lowland counterparts self-sufficient in fuel.

Space Arrangements for Fuelwood Production

As discussed earlier, where food is the major product of an agroforestry system, the tree's role may be confined to rendering service (e.g., soil stabilization, soil fertilization) rather than yielding outputs (e.g., fuelwood, timber). Under a system where the two major and simultaneous products are food and fuelwood, the trees are interplanted both for their ecological benefits and for the wood that they produce. The techniques for cultivation and interplanting for a fuelwood-producing agroforestry system are basically the same as that for the crop-producing agroforestry system. There will be only slight changes in tree and crop spacing and in the methods and timing of harvests.

As in the staple food production system, the trees and food crops in fuelwood production may be arranged in the border planting, alternate row, or alternate strip systems. Because the trees will be allowed to grow larger to produce fuelwood, however, they need to be spaced farther apart than in the fodder-yielding or green manure-producing hedgerows. Spacing trials of Leucaena by the University of Hawaii showed that 1/2-m-by-1-m spacing yielded the highest volume at age 3 (Table 1), but the widest spacing, 2 m by 1 m, had the largest average tree diameter. Because the main objective is to produce fuelwood for domestic use rather than for commercial or industrial markets, aggregate wood volume rather than tree diameter is more important, so 50 cm by 1 m spacing is best for Leucaena under conditions similar to that particular trial site, but not necessarily in others.

Other common legume trees that have potential fuelwood uses, such as Calliandra and Gliricidia, have not yet been planted in similar trials so yield-spacing relationships are not well documented. Local trials will have to be made to obtain reliable

Table 1. Comparative Growth Rates of *Leucaena* at Waimanalo, Hawaii

Spacing (m)	Population (trees/ha)	volume (m^3/ha)[a]		
		Age (years)		
		1	2	3
2 x 1	5,000	20	45	70
1 x 1	10,000	40	95	140
1/2 x 1	20,000	45	105	145
1/4 x 1	40,000	55	85	90

[a] Derived from graph; rounded off to nearest multiples of 5.

Source: R. Van Den Beldt, 1981.

information as bases for other local agroforestry-fuelwood projects.

Under the alternate strip arrangement (Figure 5), the trees at the edges of the hedge may be trimmed low for two reasons: (1) to produce animal fodder or green manure for the food crops; and (2) to reduce shading of the food crops. This arrangement would be necessary only if the trees are allowed long rotations of three years or more. If trees are harvested yearly, however, they are not tall enough to pose shading problems, and the tops and leaves will be used for green manure only when the trees are harvested for fuel.

Establishing Fuelwood Tree Crops

Fuelwood crops may be established by direct seeding, by seedlings, or by cuttings; most legume trees can be propagated by

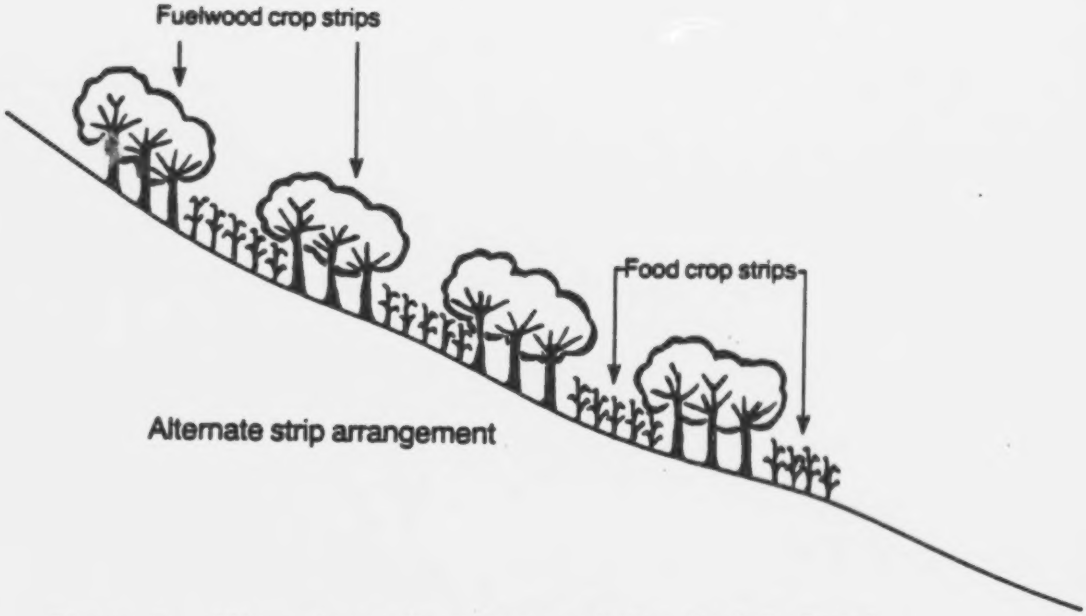


Figure 5. Alternate strip arrangement for food-fuelwood production.

any of the three methods. The choice should be based on comparative costs and survival rates. For example, use of seedlings requires establishment and operation of a nursery and transplanting of the seedlings. This approach results in added costs, but it also means higher survival and growth rates, especially since it affords an opportunity to introduce the needed Rhizobia. Transplanting often stands out as the best choice, especially in countries where labor is plentiful and cheap.

Upland food crops, unless properly terraced and irrigated, are totally dependent on rain for moisture and are usually established at the start of the rainy season. It is logical that tree crops be established under the same time schedule to ensure survival.

To make sure that the trees perform their soil-stabilizing functions effectively in addition to producing fuelwood, the rows and strips must be established along the contours or across the slope. (See Appendix on the use of an A-frame to locate contour lines.) Each strip or hedge may consist of three to five tree rows 1 m apart. The trees should be not less than 50 cm apart along the rows.

Harvesting and Regeneration for Sustained Fuelwood Yields

Assume, for illustrative purposes, that trees spaced 50 cm by 1 m yield 100 m^3 per ha (about 30 percent more conservative than the Hawaii trials) at age 3. This means that 100 m^2 of land is needed to yield 1 m^3 of fuelwood. To fill the farm family's annual fuelwood needs of 5 m^3, a tree plantation of 500 m^2 will be needed per year. This is equivalent to a five-row tree strip 4 m wide and 125 m long. Since it takes three years to grow the trees to harvestable age, each farm family should have at least three 4 m by 125 m strips of fuelwood plantations on their farm. If the family plants one strip per year, they will have three plantations on the fourth year aged one, two and three years, respectively. From that fourth year onward, they can harvest one strip per year, and there will always be one strip ready for harvest each year (Figure 6).

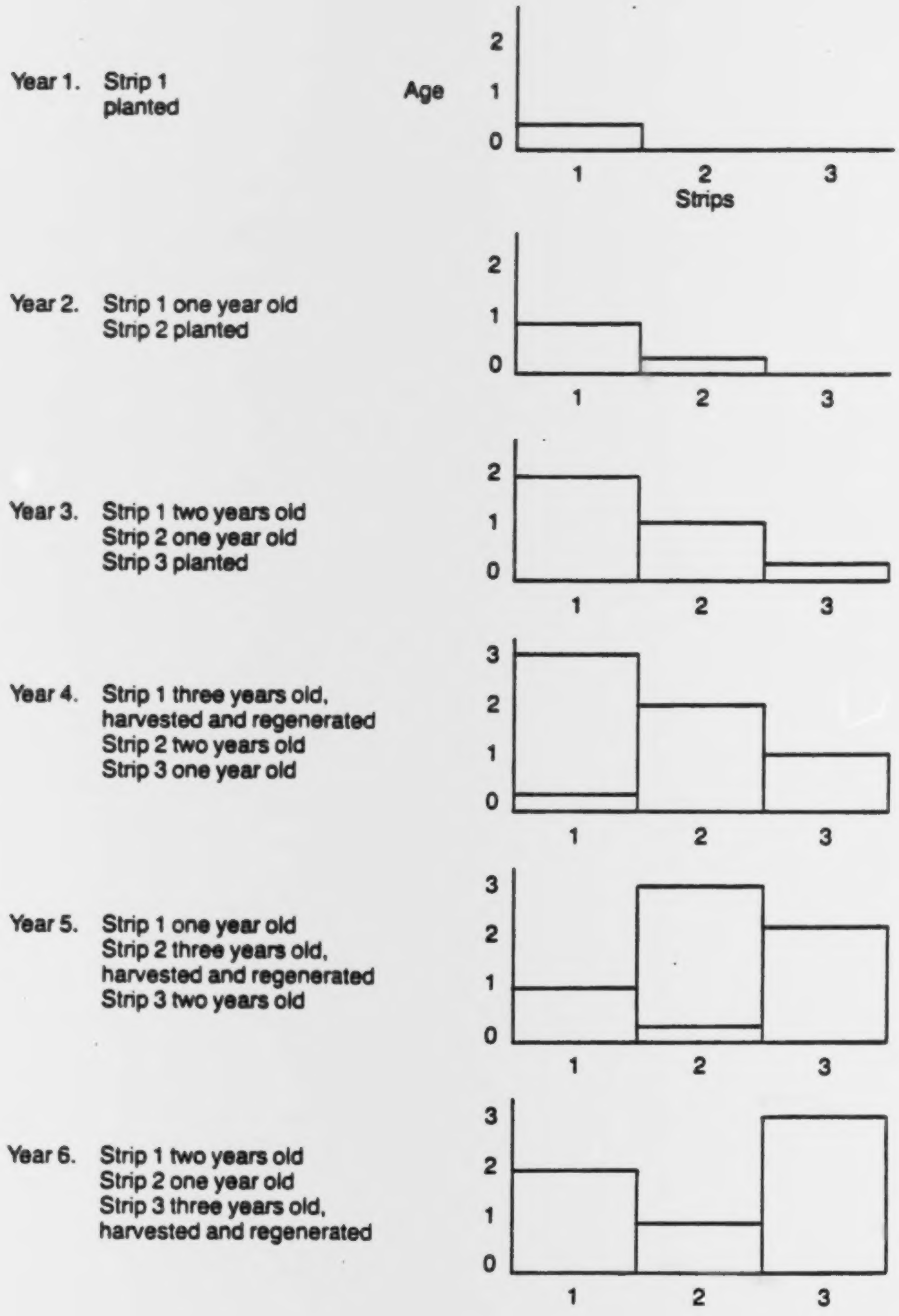


Figure 6. Fuelwood harvesting schedules for sustained production.

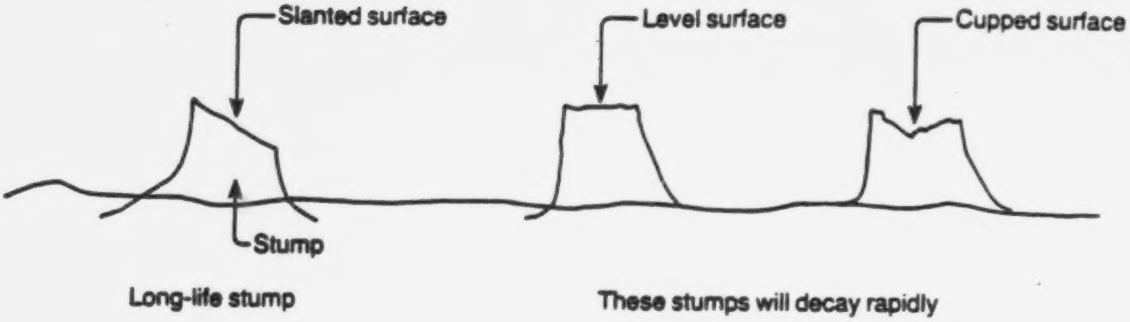


Figure 7. Stump surface configuration to prolong stump life.

Stumps of Leucaena can last for several cuttings before they decay and die. For longevity, the cut stump surface should be slanted so that rainwater will run off and reduce the chances of moisture-dependent fungi growth that causes stump decay (Figure 7). If fungi growth and decay are unavoidable, new seedlings may take over the place ot the decayed stump. Meanwhile, the fungi, if edible, may supplement the food harvested from the forest.

As in the case ot fodder production, stumps coppice more effectively when they are taller. They should be cut as short as possible, however, so that most if not all of the original tree stem is harvested and used, and so that stumps will not impede harvesting operations. Heights may vary from 10 cm to about 1 m. Waist-high stumps are often preferred because they allow the farmer to cut with knives and axes without bending.

Too much coppicing is a problem at times since crowded coppices compete with each other for nutrients and sunlight and become stunted. To counteract this, the farmer may reduce the number by cutting off the rest as soon as two to three dominant sprouts per stump can be identified for retention.

FUELWOOD PRODUCTION FOR COMMERCIAL USE

Legume trees can also be used as the basis for a commercial energy farming system. Since this approach would normally require a tree monoculture, it would not be classified as true agroforestry. In some cases, however, food crops can be interplanted with the tree crops in the early stages of the development of a forest plantation. Alternatively, the area under younger trees can be used for grazing animals if suitable ground cover is planted.

Commercial fuelwood production can be a large corporate operation or can be undertaken by small farmers. Some initial projects of this small-scale tree-farm type have begun in the Philippines and other developing countries.

Species selection and spacing will depend on the physical characteristics needed in the fuelwood produced. As mentioned earlier, there are tradeoffs in terms of total biomass produced and average tree diameter when different spacing arrangements are used. The optimal solution will involve species selection, spacing, and harvesting schedules; each end use and location may employ a separate solution.

The main end uses for wood products from commercial energy forests are: (1) the production of chips for use as a boiler fuel to produce steam for industrial or institutional use; (2) wood-fired steam production for electric power generation (dendro-thermal power); (3) the production of chemicals and liquid transport fuels through either fermentation or gasification of tree products; or (4) small-scale commercial charcoal or fuelwood production for urban markets. Rigorous technical evaluation and economic analysis are required for both large-scale and small-scale developments.

Large-scale energy forests are expensive to establish, harvest, and transport; they are subject to the vagaries of climate, attack by insects and fungi, and destruction by fire. In addition, there are significant environmental considerations that must be evaluated. Many of the environmental impacts of monoculture fuelwood forests are positive, some could be negative, and others are subject to debate but should not be overlooked.

Economic Costs

The economic costs of establishing an energy plantation are high. Key variables include land acquisition, tree establishment, maintenance (and possibly fertilization), and harvesting. Initial land selection and land procurement are keys to economic success. Many forestry schemes have been based on available land that has subsequently not proved suitable in terms of tree growth, harvesting systems, transport systems and distances, and long-term fertility. Conversely, much planning for large-scale energy forests has taken place on the assumption that land that appeared suitable was in fact available. Therefore, evaluating the availability and suitability of land is a critical initial step before economic analysis is done and before decisions are made on the establishment and extent of energy forests. Overestimates of yields from plantations or false assumptions on land availability can create major problems.

Because of the dependence on tree production as the sole or major source of income, an individual developing a commercial energy forest will need to pay careful attention to all aspects of commercial tree production. Whereas in agroforestry the mix of crops grown provides some protection in the case of failure of any one crop, in commercial energy forestry the stable and sustainable production of forest products is required to assure economic security. Inevitably, such a project, whether for a dendro-thermal unit, for use by industry as boiler fuel, for large- or small-scale charcoal production, or for the production of alcohol fuels, will be subjected to close economic scrutiny. This appraisal should also explicitly include consideration of environmental factors directly affecting tree growth. These factors include altitude, rainfall (both total rainfall and mean monthly), day length, mean day temperature, wind, and the likelihood of typhoons, cyclones, and other major natural disturbances. Other physical parameters such as soil (especially fertility, drainage, soil moisture, texture, and structure) and topography, play an important part in assessing the growth rate and usable volume of wood produced. Biotic parameters such as possible insect or disease hazards or likely animal damage may influence choice of species or rule out some sites altogether.

Environmental Factors

The development of commercial energy forests are both affected by and have an effect on the environment. The previous section mentioned some of the environmental factors that will affect the productivity of an energy forest. In turn, the forest itself will have an impact on the environment.

The establishment practices, the removal of existing cover, the extent and intensity of cultivation, the provision of drainage systems, the maintenance or loss of humus (through use of bulldozer or grader blading or through fire) will all have an effect on long-term soil fertility, soil erosion, and sustained productivity. This is especially true during the early establishment period. Harvesting, particularly the use of heavy machines that cut and chip, or through the use of machinery for extraction of roundwood, can cause compaction and disturbance that will lead to erosion. In the long run these negative effects may outweigh the benefits of tree legumes—rapid growth of biomass and the site stabilizing effect of tree cover.

Emphasis must be placed on planning all aspects of energy forest development if the promise of short rotations of nitrogen fixing trees is to provide a reliable energy source. The proposed energy forest needs to be evaluated in several ways:

- Will it cause or reduce erosion?
- Will it alter the levels of insects, animal predators, or fungal disease that will significantly affect humans and their activities?

- Will the tree spread outside the forest boundaries—if so, is this beneficial or will the species become a weed and create problems for other systems of land use?
- Will continuous harvesting of the species leach or change the nature of the soil that will in the long term affect the use of the land for successive crops of the same species or for other agricultural or forestry crops?
- Will it affect the availability of water for other uses in the area or downstream, either positively or negatively?

Since a commercial energy forest is a long-term project, both the economic and environmental dimensions have to be examined carefully to assess the short-run and long-run economic returns from, and sustainability of, such a system.

TIMBER PRODUCTION IN AGROFORESTRY

In addition to fuelwood, timber is needed in upland farm communities for purposes such as farmhouse construction, farm implements, and fencing. If markets exist, commercial timber for pulpwood and electric posts also may be produced by farmers.

The traditional sources of timber are the natural forests. Where these resources are no longer available, farmers may rely on forests interplanted with food crops in agroforestry farms.

In contrast with pure forest production, agroforestry farms usually produce small-sized timber. This is because (1) farmers generally want quick returns; and (2) they do not allow trees to grow older and larger to cause too much shading and reduce food crop yields. Farmers often harvest their timber crops in 4 to 10 years, depending on the rate of growth and on the desired end product.

In places where a pulp and paper plant buys timber from small farms, pulpwood can be an important wood product of agroforestry. Several species are suitable, but one legume tree that has been tried and found highly suitable, both from the user-company's viewpoint and from what farmers say about its fast rate of growth and ease in cultivating, is *Albizia falcataria*. On good sites and at 4-m-by-4-m spacing, it can yield from 150 to 250 m^3 per hectare at age 8. Being a legume, it also improves the soil for the benefit of interplanted food crops.

Tree Establishment and Management for Timber

The initial spacing for *Albizia* may be four meters along the row and four meters between rows (625 trees per ha). The species has a broad crown and the canopy closes quickly, but since the leaves are small and sparse, sunlight can still reach the ground. Nevertheless, it may be necessary to change food crops over the life of the tree plantation. For instance, sun-demanding cereals like upland rice and corn may be interplanted during the first two years when tree-crown openings are still wide, then replaced by more shade-tolerant root crops like taro in the second two years as the canopy closes. The forest may be thinned at age 4 by removing every other row so that the effective spacing may then be 4 m between trees in the row and 8 m between rows.

Volume harvested through thinning could be about 30 to 60 m^3 per hectare. Cereals may again be planted after thinning during the third two years, and changed to root crops once more in the last two years. Final harvest of the forest is at age 8, with a yield of around 80 to 125 m^3 per hectare.

The change in the food crop from cereals to root crops before thinning and before final harvest has one additional advantage: subsurface food products are better protected from damage during harvesting operations.

Harvesting Schedules

As in the case of fuelwood production, it is desirable to give the farmer an opportunity to earn continuous yearly incomes from timber outputs. This could be achieved by dividing the farm into eight equal parts—or as many parts as the number of years it takes for the timber to reach harvesting age. If the farmer plants trees in one part each year, he will have one mature and harvestable pulpwood plantation each year from the ninth year onward. Because *Albizia* coppices and seeds well, natural regeneration is expected to be satisfactory, and continuous outputs of pulpwood and food can be expected from the agroforestry operation.

One drawback of this combination of wood-food production is that the trees are relatively far apart and may not be as effective in stabilizing the soil as the systems that allow close spacing and hedgerow planting of trees (as in food-forage production). This weakness may be minimized by intercropping trees with food crops that require less weeding and cause less soil disturbance and, therefore, less tendency for erosion.

The techniques for growing other tree species for other types ot timber products needed on the farm would be basically the same as in the Albizia example, although there might be some differences in spacing and length of rotation as influenced by the growth rates ot the species and the end product.

APPENDIX

A-FRAME: A SIMPLE TOOL FOR ESTABLISHING CONTOUR HEDGES

Previous trials indicate that two spatial systems of agroforestry—alternate rows and alternate strips—are most effective in minimizing erosion and in conserving the soil on hillside farms. The principal requirement is that the rows or strips of planted trees must be across the slope or along contour lines in order to be effective slope stabilizers.

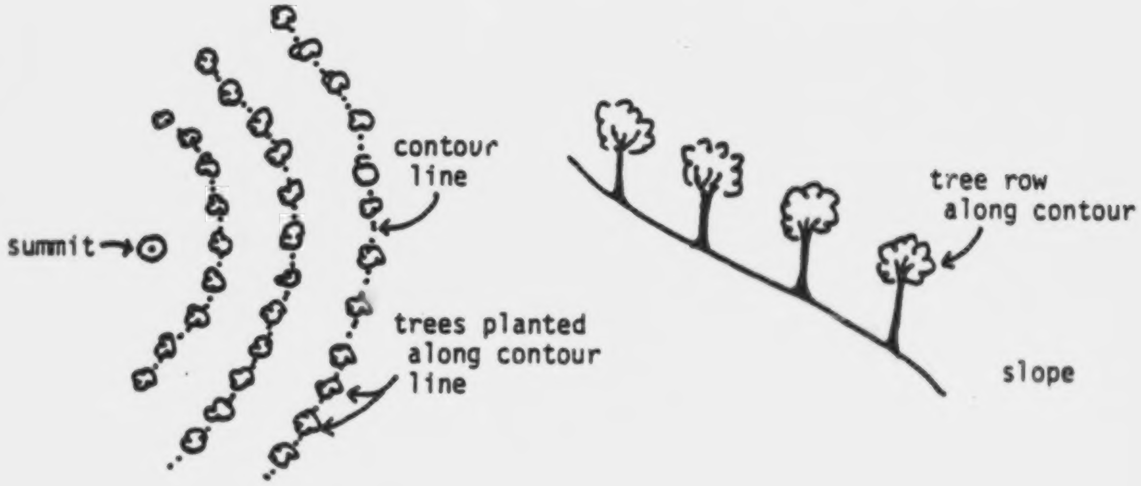
One problem faced by farmers is how to draw the contour lines first so that they can establish the tree rows or hedges along those contours and make sure that all trees along each row are planted on the same elevation, as shown in Appendix Figure 1.

There are accurate instruments for leveling such as hand-held levels or tripod-mounted levels used in surveys by geodetic engineers. There is also the carpenter's level. However, these are generally unavailable to, and too complicated for the farmers. What is needed is a simple instrument that can be easily built and conveniently and accurately used by the farmers themselves. The A-frame is one such tool. Following is an outline of instructions for building and using an A-frame.

I. How to Build an A-frame.

    1. Procure materials needed:

        a. 2 poles 1 1/2 meters long; 1 pole 1 meter long (if available, 3 cm x 5 cm lumber may be used).


summit
contour line
trees planted along contour line
tree row along contour
slope

aerial view

side view

Appendix Figure 1. Planting tree rows along countours.

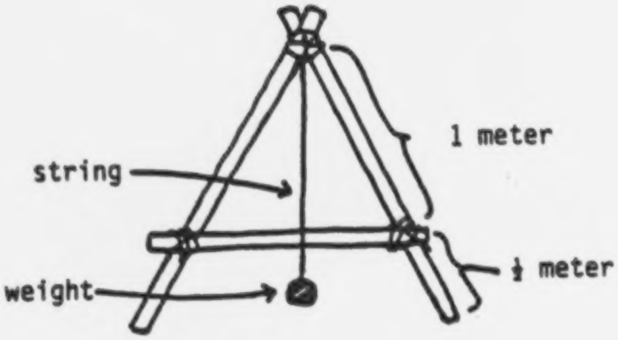
(Note: A contour is a line that connects points at the same elevation on a slope.)

b. Sufficient length of twine or string or wire (or nails) for fastening the poles together.

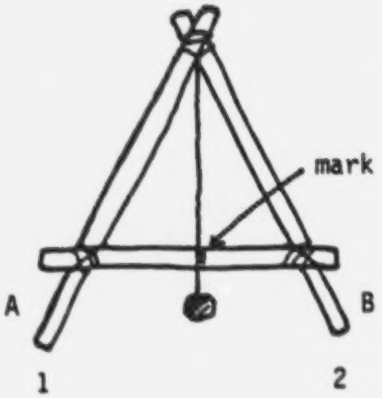
c. A piece of rock of about 5 cm diameter to be used as a weight or plumb bob.

d. A 2-meter string to hold the plumb bob.

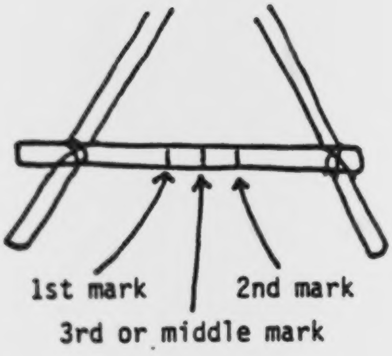
2. Build the A-frame.
    a. Lay on the ground the three poles (or pieces of lumber) as shown in Appendix Figure 2.
    b. Tie (or nail) the poles firmly together as shown in Appendix Figure 2 to form an "A."
    c. Attach the rock firmly on one end of the string.
    d. Tie the other end of the plumb bob string to the top of the A-frame such that when the A is standing, the hanging rock or plumb bob is below the horizontal bar but not touching the ground.
3. Prepare the A-frame for use.
    a. Hold the A-frame erect on approximately level ground such that leg A is on point 1, while leg B is on point 2, as in Appendix Figure 3.
    b. Mark the point where the plumb bob string touches or crosses the horizontal bar.
    c. Reverse the position of the A-frame so that leg A is placed on point 2 while leg B is on point 1.
    d. Mark also the point where the plumb bob string crosses the horizontal bar.
    e. Measure the distance between the first and the second marks on the horizontal bar and make the third or middle exactly between them, as in Appendix Figure 4.
    f. The A-frame is now ready for use. If it is held erect such that the plumb bob string touches the


1 meter
string
½ meter
weight

Appendix Figure 2. Constructing the A-frame.



Appendix Figure 3. Preparing the A-frame for use.



Appendix Figure 4. Making the middle mark on the horizontal bar of the A-frame.

middle mark, the points where leg A and leg B are standing on are of the same level or elevation.

II. How to Use the A-frame for Tracing a Contour Line on a Slope.

1. Mark point 1 (where you want to start the row of trees) on the slope. Place leg A of the A-frame on that point.
2. By trial and error, find the proper location of leg B (without moving leg A from point 1). When the plumb bob string coincides with the middle mark on the horizontal bar, mark the location ot leg B as point 2. This is on the same level as point 1. (Caution: When the wind is strong, it may push the plumb bob string from the vertical line and the A-frame may give wrong results. To avoid errors, shelter the plumb bob from the wind or avoid using the frame on windy days.)

3. Transfer leg A to point 2 and use the same process as in step 2 to locate point 3.
4. Continue the process until a series of points are established on the slope. All these points have the same elevation, and a line connecting these points is a contour. A row of trees planted along this contour line is a contour hedge.
5. Establish the next contour line (either above or below the one first made) by following the same procedures above.

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NEW DIRECTIONS IN AGROFORESTRY: THE POTENTIAL OF TROPICAL LEGUME TREES

ECONOMIC EVALUATION OF AGROFORESTRY PROJECTS

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NEW DIRECTIONS IN AGROFORESTRY: THE POTENTIAL OF TROPICAL LEGUME TREES

Economic Evaluation of Agroforestry Projects

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THE NEED FOR ECONOMIC EVALUATION

In economic evaluation of a project, the potential benefits and costs are quantified, valued, and compared. All projects require various inputs to produce one or more products—the project outputs. There also are various residuals, which are nonproduct outputs and may be good or bad; good residuals are counted as benefits, while harmful or undesirable residuals are counted as costs.

In an agroforestry project that will introduce fast-growing, nitrogen-fixing trees in combination with corn crops in an upland agricultural area, for example, the inputs required are cornseed, tree seedlings, and labor in addition to nature's free inputs of land, sunlight, and moisture. The resulting direct products (the project output) are food, fodder, green manure, fuelwood, and timber. Residuals also are generated, and some, such as nitrogen fixed in the roots and recycled to the soil as tree leaf litter or reduced soil erosion, are beneficial. Other residuals, such as increased water runoff when trees are first planted or aggressive colonization by the tree species in surrounding areas, may be harmful. While the introduction of trees in an upland system may have positive effects on water runoff and soil erosion in the longer run (positive residuals), the short-run effects may be negative or neutral depending on the cultivation practices used and the crops involved.

For proper economic evaluation, each of these inputs, outputs, and residuals must be identified and valued. For some parts, valuation is quite easy: the prices of seedlings, fertilizer, and labor are easily obtained. For other parts, valuation is much more difficult. How can the value of increased or decreased water runoff be calculated? What is the value of soil lost, or saved, by changes in erosion rates? Various techniques have been developed to evaluate these phenomena, and frequently indirect measurements of values are used.

Economic evaluation is done either before a project is begun (preproject or feasibility evaluation) to determine if the project is economically attractive or after a project is completed and some experience has been gained from its operation (postproject evaluation) to better understand the success or failure of the project. The techniques used in either case are the same. In preproject evaluation, estimated or assumed values are used for inputs, outputs, and residuals, while in the postproject evaluation actual values for quantities and prices are used. After a preproject evaluation, the project should be monitored during implementation to identify problems as well as to provide the required information for postproject evaluation.

FACTORS IN ECONOMIC EVALUATION

Before an economic evaluation is begun, several factors have to be considered and decided upon.

The Scope of The Evaluation

Any project can be evaluated at several different levels. At the lowest level, the individual farm, or even an individual field or activity unit such as corn or livestock production, is used to define the project boundary. Only those inputs, outputs, and residuals within this narrowly defined area are included in the analysis. The prices used to value the various elements are those faced by the individual farmer. This "micro" level analysis will define how a project is perceived by this individual farmer: what are the costs and what are the benefits involved from his or her point of view?

Higher levels of aggregation draw more actors and more information into the project area and broaden the analysis. For example, a village or a river basin may be chosen as the appropriate level of analysis. As the analysis becomes more "macro," additional information can be incorporated, but the differences in viewpoint increase between the individual farmer and the analyst. For example, an agroforestry project evaluated at the river basin level would include similar basic inputs (or costs) as seen by an individual farmer. The range of outputs and residuals might well be different, however, because benefits or effects that occur outside of any single farmer's field (externalities) are included in the analysis. An example of such an effect is reduced sedimentation in a downstream reservoir as a result of reduced erosion. This benefit does not go to any individual upland farmer but is enjoyed by society at large and by those who use the water and other benefits from the reservoir.

Valuing inputs, outputs, and residuals in a macro or broader analysis presents another problem. Instead of local, village-level prices faced by an individual farmer, "social prices" are often employed, reflecting the values of benefits and costs to society. In some cases these prices differ from market prices; these so-called "shadow prices" are not discussed here but are covered in basic project evaluation textbooks (see Squire and van der Tak, 1975).

Because of the differences in the inputs, outputs, and residuals measured and the prices used, the results of economic valuation at micro and macro levels may differ. What may be profitable to an individual farmer may be harmful at a larger, societal level and vice-versa. For this reason, any project evaluation should carefully define the scope of the evaluation. If agroforestry implementation is ultimately to be done by individual farmers, it is essential that a micro level analysis be undertaken. It will show whether or not the proposed change is beneficial at the farmer's level as well as at a higher, government-defined project level.

This is desirable not merely because it is considered good to have farmer participation. It is essential that individual farmers perceive the benefits of a proposed change, because it is the actions of individual farmer decision makers that result in wider effects. For example, a government program to control erosion by terracing and reforestation will only succeed if the individual landowners see the program to be personally profitable. Therefore, if the results of the analysis indicate that costs exceed expected benefits to the farmer while a broader social analysis indicates overall net benefits, the actual benefits received by farmers will have to be increased to improve the chance for farmer acceptance. Subsidies or other payments can be used to do this.

The Time Horizon

Any economic evaluation will consider a stream of benefits and costs over some period of time. The appropriate time horizon, or number of years included in the calculation, has to be determined beforehand. For some activities, such as planting an annual crop like rice or corn, the entire process is less than a year long and therefore a number of months or a year is the appropriate period of analysis. Because trees take several years to mature and then produce products over a long period of time, a longer time horizon is chosen. Periods from 10 to 20 years are common and may include several tree crop harvests; shorter periods include more of the costs and not enough of the benefits from tree crops. Information about costs and benefits occurring 20 or more years in the future generally adds little to such an analysis. This is because of discounting, which is discussed more fully later. If capital equipment is an important part of the project the appropriate time horizon would be long enough to amortize or depreciate the capital involved.

Once the scope of the analysis (defining the project boundaries and what will be included and excluded in the analysis) is decided and the appropriate time horizon (the number of years to include in the analysis) has been selected, data collection can begin. The steps in this are straightforward and are similar for most types of project evaluation. Decisions also have to be made on how to value inputs, outputs, and residuals, what discount rate to use, and what economic evaluation technique to use.

Data Collection

Information must be collected on all physical inputs, outputs, and residuals generated by the project and when they occur. These can be arranged as shown in Tables 1 and 2 in the example section of this document. It is important that as detailed and complete a record as possible is made of the various elements each year.

Project benefits and positive residuals include such things as wood, fodder, fuel, food crops, fixed nitrogen, and soil erosion and sedimentation prevented. Project costs and negative residuals include such things as money costs for inputs, labor, lost annual crop production, and land rent.

Valuation

All benefits and costs are then valued using appropriate prices. If the analysis is at the individual farmer level, local market prices can be used. If the analysis is at a national level, either market prices or social (shadow) prices can be used, depending on the situation. Two useful references for economic valuation are Gittinger, 1982, and Squire and van der Tak, 1975.

In some cases there are project benefits or costs that do not have market prices. These benefits and costs can occur onsite and offsite and include such things as changed rates of erosion or sedimentation, improved soil structure, or changed hydrologic conditions. Valuation techniques used to put prices on these and other benefits or costs are discussed in Hufschmidt et al., forthcoming.

Discount Rates

To compare costs and benefits that occur at different times, discount rates are used to calculate the present value of these future dollar amounts. Discount rates are based on the theory that the value of a dollar's worth of benefits, or costs, today is greater than the same amount of benefits, or costs, next year or any time in the future. Choosing the proper discount rate is often a problem, however. Governments and banks currently use a discount rate of between 10 to 15 percent, which is thought to reflect the scarcity value of capital. Conservationists, on the other hand, often use a very low or even negative implicit discount rate when valuing environmental goods, in the belief that the scarcity, and value, of environmental goods will increase relatively over time.

The higher the discount rate, the more present costs and benefits are valued and the less potential future costs and benefits are worth. Poorer farmers frequently have a very high discount rate, reflecting their own often marginal existence and urgent need for present consumption. Implicit discount rates of 20, 30, or even 50 percent have been measured reflecting an extremely high preference for present consumption. Exceptions to this pattern exist, of course, as seen by the planting of teak by Javanese farmers when it will only be harvested by their great-grandchildren.

The problem with this spread in discount rates is obvious. A proposed project that appears very attractive when the stream of benefits and costs are discounted back to the present at 2 or 5 percent per annum becomes only marginal at 10 to 15 percent discount rates and unattractive at higher discount rates. There is no general answer to the question of what is the correct discount rate. The fact that differences exist, however, explains why a project may be viewed as economically profitable by a government planner, using a 15 percent discount rate, and as very unattractive by a farmer, using a 30 percent discount rate. Most countries have some discount rate that is customarily used by government planners. This rate can be employed in an economic analysis, but a second analysis using a different and usually higher discount rate reflecting a farmer's perspective should be done also. This sensitivity analysis will indicate how sensitive the net benefits of the project are to different discount rates. Potential conflicts between how profitable a proposed project is seen by individuals or society are thereby highlighted.

The basic formula for discounting is as follows:

$$V_0 = \frac{V_n}{(1+i)^n}$$

where: V_0 = value of benefit (or cost) in year 0 (the present)

V_n = the money value of the benefit (or cost) occurring in year n

i = the discount rate, expressed as a decimal
(10 percent = 0.10)

$(1+i)^n$ = the expression $(1+i)$ raised to the power n

For example, if the discount rate (i) is 10 percent, the values for $(1+i)^n$ for year 1 to 5 are as follows:

Year (n)	Value of $(1+i)^n$	Present Value of $100 Received in Year n
0 (present)	$(1+0.1)^0 = 1.0$	$\frac{100}{(1.0)}$ = \$100.00
1	$(1+0.1)^1 = 1.1$	$\frac{100}{(1.1)}$ = 90.91
2	$(1+0.1)^2 = 1.21$	$\frac{100}{(1.21)}$ = 82.64
3	$(1+0.1)^3 = 1.33$	$\frac{100}{(1.33)}$ = 75.19
4	$(1+0.1)^4 = 1.46$	$\frac{100}{(1.46)}$ = 68.49
5	$(1+0.1)^5 = 1.61$	$\frac{100}{(1.61)}$ = 62.11

Since the values for $(1+i)^n$ appear in the denominator, the larger the value of this factor, the smaller the present value of some future benefit or cost. In practice, the analyst can use already calculated tables of "discount factors" to determine present values. In the discount table above, the discount factor with a 10 percent discount rate for year 3 is $\frac{1}{1.33}$ or 0.752 and, for year 5, $\frac{1}{1.61}$ or 0.621. When this discount factor is multiplied by the cost or benefit received in any given year, it gives the present value of that cost or benefit with the assumed discount rate. That is, the discount factor is determined by the year, n, and the discount rate, i.

The present value of $100, receivable in future years at different discount rates, is:

	Discount Rate (%)				
Time (years)	2	5	8	10	15
0 (present)	$100.00	$100.00	$100.00	$100.00	$100.00
10	82.03	61.39	46.32	38.50	24.72
20	67.30	37.68	21.45	14.92	6.11
30	55.21	23.14	9.94	5.73	1.51
50	37.15	8.72	2.13	0.85	0.09

Obviously, benefits or costs occurring 20 or 30 years in the future have low present values, especially when discount rates larger than 10 or 15 percent are used.

ECONOMIC EVALUATION TECHNIQUES

Many different techniques have been developed to evaluate the discounted streams of benefits and costs. Some of these techniques are explained in texts listed in the reference section.

Commonly used approaches include the Net Present Value (NPV), the Benefit-Cost Ratio (B/C Ratio), and the Internal Rate of Return (IRR). All of these use discounted streams of benefits and costs. The Net Present Value (NPV) is the basic economic value to be measured. The NPV determines the present day value of net benefits (gross benefits minus costs) of a given project with a predetermined discount rate and time horizon:

$$NPV = \sum_{j=1}^{n} \frac{B_j - C_j}{(1+i)^j}$$

where B_j = benefits in year j
C_j = costs in year j
i = discount rate (expressed as a decimal)
n = number of years (the time horizon).

If there are no capital or other constraints, one would undertake all projects with an $NPV \geq 0$; these projects would yield total benefits with a present value greater than the present value of total costs. When there are constraints—capital, management skills, or land, for example—other analytic techniques employing ratios can be used to rank alternative projects although the objective is always to maximize net present value subject to the constraints. In general, the constraining variable is placed in the denominator and a ratio is constructed of benefits and this constraining variable. In practice, costs are frequently considered as the constraint and a Benefit-Cost Ratio approach is used. In this case costs are placed in the denominator of the ratio:

$$B/C\ Ratio = \frac{\sum_{j=1}^{n} \frac{B_j}{(1+i)^j}}{\sum_{j=1}^{n} \frac{C_j}{(1+i)^j}}$$

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where B_j = benefits in year j

C_j = costs in year j

i = discount rate (expressed as a decimal)

n = number of years (the time horizon).

The B/C Ratio is closely related to the NPV calculation and is an alternative way of providing information for decision making when there is a constraint on costs. The B/C Ratio does not provide information on the amount of total net benefits; it merely calculates the ratio of discounted benefits to discounted costs.

The ratio can be greater, equal to, or less than one (unity). If the B/C Ratio equals 1.0, the *present value* of all measured costs is just equal to the *present value* of all measured benefits. There is no "profit." If the B/C Ratio is greater than 1.0, the present value of benefits is larger than the present value of costs, and the project is economically "profitable" at the chosen discount rate, i. The reverse is true if the B/C Ratio is less than 1.0.

The sign of the NPV and the size of the B/C ratio are related since they are similar approaches. If an NPV is *negative*, this is the same as a B/C Ratio of less than 1.0; a zero NPV is equal to a B/C Ratio of 1.0; and a positive NPV is equal to a B/C Ratio of more than 1.0.

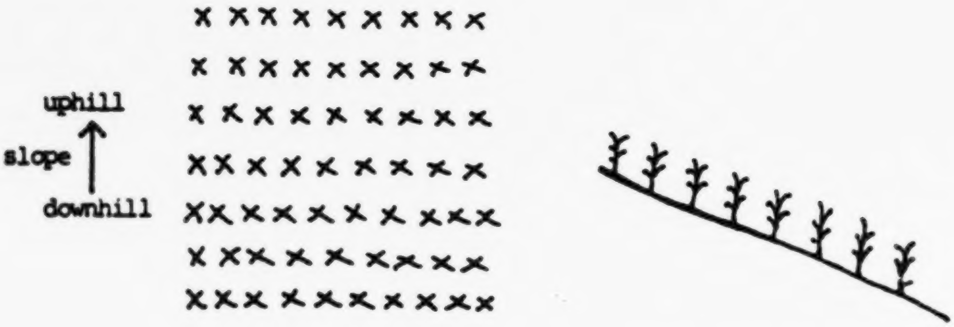
A third approach, the Internal Rate of Return, is similar to the NPV calculation, but instead of setting a discount rate, i, it sets NPV = 0 and solves for i. That is, it gives the discount rate that will set the NPV equal to 0 or define a B/C Ratio of 1.0. Once this discount rate, i, the IRR, is calculated, it can be compared to current interest rates or the social cost of money. For example, if the IRR of a project is 22 percent but the cost of money is 15 percent, the project is economically attractive since it would take an interest (discount) rate of 22 percent to make the present value of benefits equal to the present value of costs. Since the cost of capital is only 15 percent, the extra 7 percent (22 minus 15 percent) is a measure of profitability.

All of these approaches are commonly used in project evaluation, but the NPV and B/C Ratio can be more easily calculated by hand and therefore may be more useful in the field. If several projects are under consideration and funds are not sufficient to undertake all of the projects, the various alternatives can be evaluated and their B/C Ratios ranked as an aid to budget allocation. Of course, this approach depends heavily on the discount rate chosen. As discussed previously, sometimes the same project is evaluated at several discount rates (sensitivity analysis) to see how much this changes the results and the ranking among alternative projects.

A SIMPLIFIED EXAMPLE

In this example, an upland farm of 2 hectares has traditionally been planted in corn twice a year. Being introduced is an agroforestry project with alley cropping of Leucaena with corn; that is, alternate strips are planted to corn and to Leucaena, a fast growing, nitrogen-fixing tree (Figure 1).

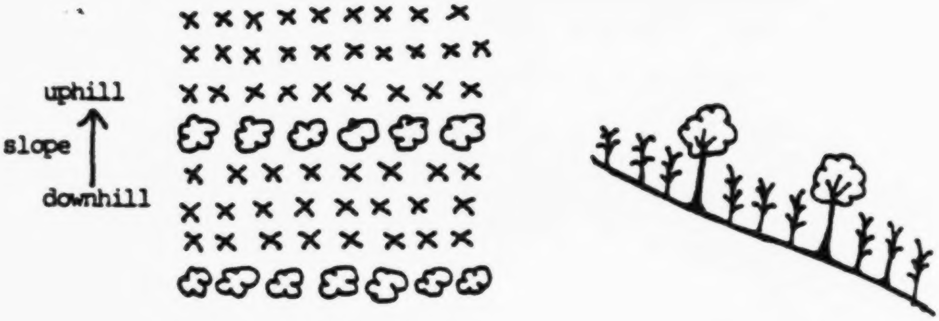
Existing corn-monoculture system:


uphill
slope
downhill

Top View

Side View

Proposed agro-forestry system:


uphill
slope
downhill

Top View

Side View

Figure 1. Existing and proposed agricultural systems.

Before the trees were introduced, no fertilizer was used on the upland corn and yields were 1 ton per hectare. It is assumed that under the old system corn yields remain unchanged, although in practice they will decrease over time if leached soil nutrients or eroded soil are not replaced. When the Leucaena trees are planted, a part of the corn crop is replaced with trees and some corn production is lost. The trees replace 20 percent of the corn crop, with 2,000 seedlings per hectare under the new alley cropping system (a seeding rate of 10,000 tree seedlings per hectare, pure stand). One hectare of land that was formerly entirely planted in corn now contains 0.8 ha of corn and 0.2 ha of Leucaena.

The corn crop requires 6 workerdays (WD) per hectare to plant each crop and harvesting requires another 6 WD per hectare per crop. No material inputs are used for the corn crop other than seeds at a rate of 20 kg per hectare.

The tree crop project requires land preparation at a rate of 5 WD per hectare. This occurs only once, in year 1. Planting the Leucaena trees on 20 percent of the land requires another 5 WD per hectare. It is assumed that the various tools required for corn or tree production are already available to the farmer, and their costs are not included in the analysis. Furthermore, it is assumed that the farmer owns the land and therefore no rent is paid or included; if the land were rented, this would be an additional cost of production to the farmer.

Various products are produced under the new agroforestry system. Corn yields increase to a rate of 1.5 tons per hectare (or 1.2 tons per mixed agroforestry hectare, 0.8 X 1.5 = 1.2) because of the nitrogen-rich leaf litter from Leucaena, and the improved soil characteristics after the trees are established. The Leucaena trees are harvested every three years (years 3, 6, 9, etc.) and, at those times, fodder is also collected. Wood yields are 30 m^3 and fodder yields are 1 ton (dry matter) per agroforestry hectare planted with 80 percent corn and 20 percent trees. Harvesting the trees and fodder collection require 10 WD per agroforestry hectare at the stated tree density.

The economic analysis will therefore compare the two alternatives: pure corn cropping (the without-project case) and the new agroforestry system integrating tree cropping with corn (the with-project case). A Net Present Value calculation will allow a comparison of these two alternatives. An NPV analysis on the proposed new system alone will show if it is profitable by itself (NPV > 0), but it will not demonstrate that it is necessarily better than the existing system. However, an NPV analysis of the alternatives will measure for the farmer the net returns of the two systems and will clarify the choice faced by the farmer as to whether or not to adopt the new system.

For simplicity, a 12-year time horizon is selected and the various inputs, outputs, and residuals are identified. Monetary values are assigned to these variables:

Labor	US$3.00 per workerday (WD)
Corn seeds	0.60 per kg
Corn crop	150.00 per ton
Leucaena seedlings	0.05 per seedling
Wood	10.00 per m^3
Fodder	70.00 per ton
Discount rate	10 percent (0.10)

Table 1. Yearly Inputs and Outputs Per Hectare (2 Crops) for Corn Cropping

Activity, Inputs, and Outputs (per corn crop)	Year 1	2	3	4	....	12
Planting (6 WD)	12	12	12	12	....	12
Harvesting (6 WD)	12	12	12	12	....	12
Seed Rate (20 kg)	40	40	40	40	....	40
Yield (1 ton)	2	2	2	2	....	2

The analysis will compare the with and without situations—the proposed agroforestry system and the existing corn monoculture. The without case is the preproject situation and can be evaluated easily. First, the physical characteristics are described. Corn is planted twice a year and the inputs and outputs associated with each corn crop are known (Table 1). Each activity input or output has a cost associated with it and, when the quantity is multiplied by the cost, the dollar value of the input or output per hectare per year is obtained.

The preproject situation can thus be easily valued; the yearly costs and benefits per hectare are as follows:

Costs	Planting	12 WD x US$	3.00 =	US$ 36.00
	Harvesting	12 WD x	3.00 =	36.00
	Seed	40 kg x	0.60 =	24.00
				US$ 96.00
Benefits	Corn Crop	2 ton x	US$150.00 =	US$300.00

The NPV is calculated as defined before:

$$\sum_{j=1}^{12} \frac{300 - 96}{(1+.10)^{j}} \quad \text{or} \quad \sum_{j=1}^{12} \frac{204}{(1.1)^{j}}$$

This value is calculated for each year 1, 2, ... 12 and these discounted present values are added:

Year			
1	$\frac{204}{(1.1)^{1}}$	=	US\$ 185.45
2	$\frac{204}{(1.1)^{2}}$	=	168.60
3	$\frac{204}{(1.1)^{3}}$	=	153.27
$\vdots$			
8	$\frac{204}{(1.1)^{8}}$	=	95.17
$\vdots$			
12	$\frac{204}{(1.1)^{12}}$	=	65.00
Sum of Years 1 to 12			US\$1,370.00

The Net Present Value of the existing system, measured over 12 years and using a 10 percent discount rate is therefore calculated to be US$1,370.00 per hectare.

Table 2. Yearly Inputs and Outputs Per Hectare (2 Corn Crops Per Ha) in an Agroforestry System

Activity, Inputs, and Outputs	Year 1	2	3	4	5	6	7 ... 12	
Corn Production								
Planting corn (WD)	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6
Harvesting corn (WD)	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6
Seed (kg)	32	32	32	32	32	32	32	32
Corn yield (tons)	1.6	2.4	2.4	2.4	2.4	2.4	2.4	2.4
Tree Production								
Land preparation (WD)	5	-	-	-	-	-	-	-
Planting trees (WD)	5	-	-	-	-	-	-	-
Harvesting trees (WD)	-	-	10	-	-	10	-	10
Seedlings	2000	-	-	-	-	-	-	-
Wood yield (m^3)	-	-	30	-	-	30	-	30
Fodder (tons)	-	-	1	-	-	1	-	1

The new, proposed agroforestry system is more complicated. There are added costs for seedlings, tree planting, and wood harvesting, but there are also added benefits from increased corn yields and wood and fodder production. Again, a table defines the physical inputs and outputs of the system over the planning horizon (Table 2).

The approach is the same as in the corn cropping example. For each year, 1 to 12, the physical quantities are multiplied by the unit prices and costs and benefits are added together. In this example, all items listed are costs (have a negative sign) except for corn yields, wood, and fodder. In the table, corn and tree production have been separated to show the two sets of activities, but in the analysis they are combined. It should be noted that the corn figures are different from the first example when compared on a per hectare basis. The agroforestry system requires that 20 percent of each hectare be planted in trees and therefore only 80 percent of each hectare is in corn. Thus labor required for planting (or harvesting) per year is: 6 workerdays per crop per hectare x 0.8 hectare x 2 crops = 9.6 WD.

Using the prices given earlier, the dollar values for the physical inputs, outputs, and residuals of the agroforestry system are as follows:

Table 3. Yearly Benefits and Costs of Agroforestry System

	US$ Per Year (per hectare)								
	1	2	3	4	5	6	7	...	12
Benefits									
Corn yield	240	360	360	360	360	360	360	...	360
Wood yield	-	-	300	-	-	300	-	...	300
Fodder	-	-	70	-	-	70	-	...	70
Total	240	360	730	360	360	730	360		730
Costs									
Corn planting and harvesting	57.6	57.6	57.6	57.6	57.6	57.6	57.6	...	57.6
Corn seed	19.2	19.2	19.2	19.2	19.2	19.2	19.2	...	19.2
Land preparation for trees	15	-	-	-	-	-	-	...	-
Tree planting	15	-	-	-	-	-	-	...	-
Seedlings	100	-	-	-	-	-	-	...	-
Tree harvesting	-	-	30	-	-	30	-	...	30
Total	206.8	76.8	106.8	76.8	76.8	106.8	76.8		106.8

The values for benefits and costs for years 2, 4, 5, 7, 8, 10, and 11 are the same and the values for years 3, 6, 9, and 12 (years of forest harvest) are also the same. The net benefit for each year (benefit minus cost) is calculated and then the 12 figures are discounted as in the preceding example. In this case the figures are as follows:

Year	Net Benefit (US$) (B_j-C_j)	Present Value (US$) Discounted at 10%
1	33.2	30.18
2	283.2	234.05
3	623.2	468.22
4	283.2	193.43
5	283.2	175.84
6	623.2	351.78
7	283.2	145.33
8	283.2	132.11
9	623.2	264.30
10	283.2	109.19
11	283.2	99.26
12	623.2	198.57
	Sum of Years 1 to 12	$2,402.26

The Net Present Value of the new, proposed agroforestry system is US$2,402.26 per hectare or almost twice as large as the NPV of the corn cropping monoculture system. The new change would appear to be economically attractive and, if the numbers are correct, appealing to the individual farmer.

An analysis such as this can be further refined. More information can be obtained on the physical quantities involved and more care paid to prices. Will yields really be as anticipated? Will prices be higher or lower in the future? Is 10 percent the proper discount rate to use or should a higher rate be used? There may be considerable uncertainty about estimated yields, costs, and returns. Sensitivity analysis can be carried out by varying the values for certain parameters that are likely to be somewhat uncertain. This sensitivity analysis will indicate how sensitive a result is to changes in expected outcomes.

This example is a simplified abstraction from reality. In practice, the analyst will need to spend time in the field in order to understand the systems being compared, what the actual inputs, outputs, and residuals are, and what the farmer's perspective is. An understanding of the farmer's view of a proposed system and his or her reservations or uncertainties are crucial for conducting a realistic, and sensitive, analysis.

A more important question might be why is the proposed system not already adopted if the benefits are so obvious? The answer may be lack of knowledge on the part of the farmers; the answer may also be errors on the part of the analyst. Some costs may not have been included and some benefits may have been overstated. Anything new that appears too good to be true often is just that—too good to be true. Caution and careful counting of physical flows and the implicit prices are always crucial.

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NITROGEN-FIXING TREE RESOURCES: POTENTIALS AND LIMITATIONS

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Summary

Nitrogen (N_2) fixing trees are discussed with special attention to their use as fuelwood, forage or green manure in the tropics. Severe deforestation is viewed as leading to a "balding of the tropics" that could jeopardize the genetic resources of many legume trees. Increasing fuel and fertilizer costs mandate the planting and husbandry of tropical fuelwood and green manure tree crops. High population densities giving maximal annual biomass yields, and the use of trees with little concern about conformity or beauty, will provide attractive targets for breeder and/or agronomist/silviculturist.

N_2-fixing genera with special value as fuelwoods, forages, green manures or nurse trees, ornamentals, and as timber are listed. Characteristics are given for 18 fast-growing N_2-fixing trees in current University of Hawaii network trials.

THE BALDING OF THE TROPICS

It is traditional for man to plant and grow his food, but not to grow the wood with which to cook it. In the world of 1900 AD, the hunting and collection of fuelwood from native forests presented little challenge. There were only 1.6 billion people in the world, and approximately seven billion ha of forests. In the world of 2000 AD, however, the challenge of finding fuelwood will be awesome (Food and Agriculture Organization (FAO), 1980). A world population of 6.4 billion is predicted for 2000 AD, with only 3.0 billion ha of remnant forests (down from 4.8 billion in 1950).

The "people vs. trees" problem is greatly exacerbated in the tropics, where most countries have doubled their human populations in only the past three decades, while cutting their forest lands by half. Forest depletion figures for developing countries are startling (see Table 1). Forest areas with closed

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TABLE 1: World forest resources as totals of closed forest area and stock growing (adapted from Barney, 1978).

Region	Total closed forest area (10^6 ha)	
	1978	2000[1]
Tropics		
Latin America	640	380
Africa	230	180
Asia/Pacific	400	200
Total	1270	760
Temperate[2]	1620	1610

[1] By comparison, total world forests in 1950 exceeded 5000 million ha.

[2] North America, Europe, USSR, Japan, Australia, New Zealand.

canopy (including growing stock) that totaled 1,270 million ha in 1978 are predicted to drop to 760 million ha by the end of this century (Barney, 1978). The ramifications of this loss are staggering, but include possible effects on atmospheric carbon dioxide and world climate (Woodwell, 1978). In contrast, only a slight loss is anticipated from the 1,620 million ha of closed forests in developed countries. This may be recalled as the century when Planet Earth grew a giant bald ring around its equator. The planting and husbandry of fuelwood in the tropics is clearly mandated for the future.

It has also been traditional for man in the tropics either to allow nature to repair the soil losses to agriculture by the fallowing of land for 15-20 years, or to use inorganic fertilizer. The slash and burn tradition can no longer continue into the 21st century, as the forest depletion and man's population pressure simply obviate it. Neither can inorganic fertilizers be an economic option except for the limited, wealthy fraction of farmers. Thus, the planting and husbandry of green manure crops also becomes a mandate for the future.

The majority of tropical legumes are woody perennials, many of which are both energy producing and nitrogen (N_2) fixing. It may be asserted that the health of many tropical forests relies initially on leguminous trees for N_2 fixation. Wild populations of native or aggressive introduced leguminous trees are increasingly valued as fuelwoods (National Academy of Science (NAS), 1980) and to a lesser extent as green manure trees (NAS, 1979). Notable among these are the mimosoids, a subfamily of legumes that includes about 2800 species, predominantly tropical trees and shrubs.

Maximization of biomass/ha per year must be the immediate target for both fuelwood and fertilizer production by trees. Reduced to essentials, the number of carbon and N atoms fixed annually per unit area becomes the goal, with little consideration of tree form or appearance. It is a target more familiar to agronomists than to foresters, and one that gives the plant breeder free rein.

It is safe to predict that fuelwood and fertilizer tree production will be dominated within a few decades by trees that are agriculturally versatile and easily bred and managed. The future improvement of these legumes could, however, be limited by the availability of appropriate germplasm. With the accelerating loss of virgin tropical forests, these native resources are dwindling and are often endangered.

GENETIC RESOURCES FOR N_2-FIXING TREES

The Nitrogen-Fixing Tree Association (NFTA), a new international organization that aims to encourage research and communication on leguminous trees, was incorporated in Hawaii in 1981. A primary thrust of the NFTA is to help identify genetic resources and stimulate their careful preservation and expansion. Our present impression is that the genetic resources of N_2-fixing trees are in a tragic state. There are no major international repositories of legume tree germplasm, whether as seed, or in arboreta, and very few tree species have been the subject of botanical expeditions for germplasm collection. Additionally many of the genera of N_2-fixing trees are taxonomically confused, from unknown centers of origin, or from areas that are rapidly becoming treeless. Seeds available for distribution are often of unknown origin. Genetically distinct varieties are available for only a few species, and these are predominantly ornamentals.

The opportunities for exploitation of the genetic diversity in legume trees can be illustrated from studies with *Leucaena leucocephala* (known also as ipil-ipil, huaxin, guaje, leadtree, lamtoro, koa haole, or kubabul). These have been reviewed by Brewbaker & Hutton (1979) and other authors (NAS, 1977; Brewbaker, 1980). The arboreal leucaenas did not become naturally dispersed through the tropics, but only a shrub known as the "common-type" or "Hawaiian-type" *Leucaena*. Though our collection of this heavily flowering shrub includes more than 500 accessions from numerous countries in the tropics, there is little genetic variability. We surmise that all originated from a narrow gene base. The species was dispersed from its native Mexico mainly through Spanish galleons departing from Acapulco and Mazatlan. In this region a highly flowering shrub is the only representative of the species, and it is clearly this one self-pollinated variety that circled the world.

The tree form and other genetic variants of *Leucaena* occur in southern Mexico and in Central America, a center of diversity for this tetraploid species (which is an evident hybrid of two other species). The arboreal types were first considered a distinct species by botanists; then came to be known as the

"Salvador type." This type first came to Hawaii from Central American seed collectors in the 1930's, and was then widely dispersed in the 1960's as a result of research in Hawaii and in Australia (Brewbaker, 1975). As a source of fuelwood, the Salvador type exceeds the common type by over 100% in wood yield; yet differs by very few genes.

It is virtually certain that genetic gains similar to those in *Leucaena* await the first plant explorers for species grown solely as C or N_2 fixers. Since many of these species are outcrossing, unlike *Leucaena*, the identification of genetic superiority will require more care in seed production. However, such species may well afford greater genetic gains —as occurred in poplar and pine— through exploitation of hybrid vigor in controlled crosses or from seed orchard synthetics.

The hazards of endangerment of species are evident in *Leucaena*. The center of origin of the Salvador type appears to be in the Morazan province of southern Salvador, a region now virtually treeless. Salvador-type leucaenas are now to be found only in the city squares and in backyards, a poor genetic sample of what existed as little as 50 years ago. Leguminous trees are often selectively browsed by feral animals and are, thus, more apt to extinction than many others. Following fire, however, they often regrow with ferocity from the fire-scarified seeds that have long lain dormant in the soil.

IMPORTANT GENERA OF N_2-FIXING TREES

The 18,000 species of legumes (Family: Leguminosae) include the vast majority of important N_2-fixing trees and shrubs, many of which are in the predominantly woody subfamilies Mimosoideae (2800 spp.) and Caesalpinioideae (2800 spp.). Relatively few of the 12,000 species of Papilionoideae are arboreal, but some of these are of great economic importance. A high proportion of the tested mimosoids (92%) are able to fix N_2, contrasted with the papilionoids (94%) and the caesalpinioids (34%). A few nonleguminous tree genera also fix N_2, notably the temperate genus *Alnus* and the tropical *Casuarina* (Stewart, 1967; see p. 427).

Leguminous trees produce some of the outstanding luxury timber of the tropics (NAS, 1979). Notable among these are the papilionaceous genera *Dalbergia* (rosewood), *Perocopsis* (African teak), *Pterocarpus* (narra), and the caesalpinioid genus *Intsia* (ipil, Moluccan ironwood). Other important timbers include the mimosoids *Acacia, Lysiloma, Parkia,* and *Samanea*. Preferred timber species often exceed 30 m in height and are of slow-to-intermediate growth rates. With their high intrinsic value, such trees might wisely be interplanted at wide spacing (e.g., 100/ha) in plantations of fast-growing legumes, as a long-term investment.

The legume trees best known as ornamentals, offering striking displays of color when in flower, are predominantly in the Caesalpinioideae, many of which do not fix N_2. The ornamental legumes include:

Caesalpinioideae: *Amherstia*, *Barklya*, *Bauhinia*, *Brownea*, *Caesalpinia*, *Cassia*, *Colvillea*, *Delonix*, *Peltophorum*, *Saraca*, and *Schotia*.
Mimosoideae: *Calliandra*, *Samanea*.
Papilionoideae: *Butea*, *Erythrina*, *Sabinea*, *Sophora*.

Several tree legumes provide valuable gums (*Acacia* spp.) and the pods of several species are excellent human foods, including:
Caesalpinioideae: *Ceratonia* (carob), *Tamarindus* (tamarind).
Mimosoideae: *Inga*, *Parkia*.

The following discussions will focus on legume trees with special significance as sources of energy or green manure. As a generalization, most fast-growing legume trees are mimosoids. Genera to be considered in the discussions of energy and green manure are listed below, together with their approximate number of species:
Caesalpinioideae: *Acrocarpus* (3), *Cassia* (600), *Schizolobium* (5).
Mimosoideae: *Acacia* (600), *Albizia* (100), *Calliandra* (100), *Desmanthus* (40), *Enterolobium* (8), *Inga* (200), *Leucaena* (10), *Lysiloma* (35), *Mimosa* (450), *Parkia* (40), *Pithecellobium* (200), *Prosopis* (44), *Samanea* (1).
Papilionoideae: *Dalbergia* (250), *Erythrina* (100), *Flemingia* (35), *Gliricidia* (10).

WOOD AND FUELWOOD

World production of wood in 1975 exceeded 2.5 billion m^3 (World Bank, 1978). Less than a century ago, wood was the major energy source for all countries in the world. Today, only 45% of the wood harvested is for fuel, and this is almost entirely in the tropics. Industrial uses of wood (60% in construction, 25% for pulp, 15% for other uses) have increased far more rapidly than total world commodity trade. These uses govern the base price of wood and directly influence both the availability and cost of fuelwood in the tropics. Demand for industrial wood has been increasing at about a doubling rate every 25 years. Demands for fuelwood are also increasing and will soon exceed capacity in regions such as Asia, which has less than 0.18 ha of forest per person at present (Revelle, 1980).

Tree legume species considered of special significance for fuelwood are summarized in Table 2. Species with unusual adaptability to the arid tropics are distinguished. Although many of these species appear to be slow in growth in their native habitats, they are often fast growing under experimental conditions, notably with adequate water. Species of *Acacia* and *Inga* provide fuelwoods for tropical highlands, while temperate fuelwoods would also include species of *Gleditschia* and *Robinia*.

TABLE 2: Tropical tree legumes of special significance as fuelwood (adapted from NAS, 1980).

Genus	Species adapted to:	
	Humid tropics	Arid tropics
Acacia	*auriculiformis, mearnsii*[1]	*brachystigia, cambagei, cyclops, nilotica, saligna, senegal, seyal, tortilis*
Albizia		*lebbek*
Calliandra	*calothyrsus*	
Cassia		*siamea*
Derris	*indica*	
Gliricidia	*sepium*	
Inga	*vera*[1]	
Leucaena	*leucocephala*	
Mimosa	*scabrella*	
Pithecellobium		*dulce*
Prosopis		*alba, chilensis, cineraria, juliflora*[2]*, pallida, tamarugo*
Sesbania	*grandiflora*	

[1] Highland-adapted species.
[2] Widely considered an undesirable, thorny pest.

Dendrothermal power plants can be designed to use chips (conventionally) or roundwood. Choice of fuelwood stock is influenced primarily by heat production (combustion value), and by ease of sawing, chipping, and transportation. Combustion values and wood densities are summarized in Table 3 for the species included in the University of Hawaii studies. Combustion values (given for bone-dry wood) reflect wood chemistry; not density, and vary little for the species listed. These values decrease linearly as wood moisture increases (most fuelwoods contain about 50% moisture at harvest). Specific gravity of species like the fast-growing *Albizia falcataria* are too low to make commercial fuelwood, due to bulk density problems of transportation and handling for the boiler. On the other hand, some species are so dense (e.g., arid-zone *Acacia and Prosopis* spp.) that they present problems in sawing and chipping. An economic feasibility analysis in Hawaii (Brewbaker, 1980) concluded that giant leucaenas could be grown and

TABLE 3: Characteristics of N_2-fixing trees in University of Hawaii international network trials (Scale: 1, Good – 3, Poor).

Characteristics	*Acacia auriculiformis*	*Acacia mangium*	*Acacia mearnsii*	*Acrocarpus fraxinifolius*	*Albizia falcataria*	*Albizia lebbek*	*Calliandra callothyrsus*	*Casuarina equisetifolia*	*Dalbergia sissoo*	*Enterolobium cyclocarpum*	*Gliricidia sepium*	*Leucaena diversifolia*	*Leucaena leucocephala*	*Mimosa scabrella*	*Prosopis pallida*	*Samanea saman*	*Schizolobium parahyba*	*Sesbania grandiflora*
Utility for:																		
Forage	3	3	2	3	2	1	2	3	2	2	1	1	1	3	1	2	3	1
Fuelwood	1	2	1		3	1	1	1	1	2	1	1	1	1	1	3	3	1
Roundwood	3	2	1		3	1	3	1	2	3	1	1	1		3	3		1
Lumber	3	1		1	2	2	3	3	1	1	3	3	3	2	2	1	3	3
Pulpwood	1	1	1		1		3	2	2	1	3		1	1	3	2	2	2
Green manure	3	3	2	3	2	1	1	3	2	3	1	1	1	1	2	3	3	1
Craftwood	3	2		2	3	1	3	3	1	1	2		2		1	1	3	3
Food	3	3	3	3	3	3	3	3	3	2	2	3	1	3	2	2	3	1
Tolerance of:																		
Acid soils	1	1			2?		2?	1				3	3					3
Cold soil	2	2	1	3	2	1	2	2	1	3	3	2	3	1	3	3	2	3
Drought	3	3	2	3	3	2	2	1	1	1	2	1	1		1	1	2	2
Min. rain (mm)	120	150	100	100	150	60	100	30	50	75	150	60	60		25	60	75	100
Coppicing ability	2	1	1		1	1	1	2	1		1	1	1		2			1

harvested profitably as boiler fuel, even with Hawaii's high costs of labor, land, and water. Energy returns from a 1000 ha tree farm, harvested incrementally on a four-year cycle, were calculated to be 28.6 million kwh annually. Wood drying and use of high efficiency boilers could increase this value by 20%.

Choice of fuelwood for home use involves many considerations. Local preferences dictate a wide array of species in the arsenal of the agroforester. Most simple stoves are designed to accomodate long pieces of wood that are fed into the stove as they burn. Most labor- and energy-efficient stoves are closed in order to minimize air intake, and so require specific, cut lengths. Split wood dries rapidly and is often favored over round wood, although marketing is conventionally by volume; not by weight. Irregular, heavily knotted woods (e.g., many acacias, prosopis) are difficult to prepare or split as fuelwood, but may be preferred for charcoal. Smokiness, ash content, explosive inclusions, thorniness, odor, and uniformity of burn can influence home fuelwood value. Many of these traits could be addressed profitably by the plant breeder and silviculturist. As an example, thornless mutants are found in several of the thorny mimosoids (Felker, 1979).

GREEN MANURE AND NURSE TREES

Leguminous shrubs and trees are of increasing interest as sources of "green gold" (Curran, 1976) for the fertilization or nursing of both herbaceous and tree crops in the tropics. Green manuring of herbaceous crops is a sadly neglected area of tropical research. Legume trees like *Leucaena* and *Sesbania* can be continously coppiced for harvest of leaf meal. The clippings, which are high in N, can be placed directly around an interplanted crop, or "cut and carried" for incorporation prior to planting. Guevara, Whitney & Thompson (1978) showed that annual N yields of 0.5 t/ha can be obtained from *Leucaena* harvested every three months. Similar estimates may be inferred from earlier studies in the authors' laboratory. The availability of inorganic fertilizers has discouraged research on green manures in the tropics until recently. Definitive, quantitative data on N recovery and utilization from leguminous forage remains a serious need. Initial studies of R.A. Bradfield (personal communication) on leucaena green manuring of maize at IRRI were very promising. Guevara (1976) later quantified this relationship in Hawaii, recording excellent maize yields and effective recovery of about 46% of the N applied as leaf meal. An extensive demonstration of these methods is underway by the Philippine National Food and Agriculture Council. Legume trees of special merit for green manure research include the widely used *Sesbania* spp., *Leucaena leucocephala* and *Gliricidia sepium* (annually deciduous); also *Acacia mearnsii, Albizia* spp., *Calliandra calothyrsus,* and *Mimosa scabrella.*

TABLE 4 Properties of N_2-fixing trees in University of Hawaii international network trials.

Property	Genus and Species																	
	Acacia auriculiformis	*Acacia mangium*	*Acacia mearnsii*	*Acrocarpus fraxinifolius*	*Albizia falcataria*	*Albizia lebbek*	*Calliandra callothyrsus*	*Casuarina equisetifolia*	*Dalbergia sissoo*	*Enterolobium cyclocarpum*	*Gliricidia sepium*	*Leucaena diversifolia*	*Leucaena leucocephala*	*Mimosa scabrella*	*Prosopis pallida*	*Samanea saman*	*Schizolobium parahyba*	*Sesbania grandiflora*
Specific gravity	.68	.65e[1]	.65	.63	.33	.58	.65	1.00	.68	.50	.75e	.55e	.54		.80	.52	.32	.42
Wood yield m^3/ha.yr.	15	30	20e		40	5	50	15		8e	8e	25e	45		8e	15e	20	22
Average caloric value (Kcal/g)	4.8					5.2	4.6	5.0	5.0		4.9		4.6					
Average annual height growth (m)	2.6	2.5	4e	2.0	5.0	1.4	6.0	2.1	2e	2e	25e	4.0e	4.5	4.5	2.5e	2.5e	1.9	3.3
Height at maturity (m)	30	30	25	60	45	30	10	30	30	30	10	20	20	15	20	45	30	10
DBH at maturity (cm)	60	25	50e	300	200	200	20	30	200	200	20e	20e	35	30	60	180	70	30

[1] e = estimated values.

The interplanting of leguminous trees as nurse crop to other trees evolved out of the tradition of shading crops like coffee and cacao. Shade may in fact be a disadvantage offset by the N-rich leaf drop in many plantations. Among the major nurse legumes for plantation crops are *Albizia carbonaria, Erythrina* spp., *Flemingia congesta, Inga* spp. and *Leucaena* spp. (*diversifolia, leucocephala* and *pulverulenta*). *Flemingia* is notable for its tolerance of acid rubber plantation soils, as is *Acacia auriculiformis.*

Tree legumes can also be used as living fences or support systems for other crops. Studies at the International Institute of Tropical Agriculture (IITA) (1979) have demonstrated the practicality of using *Leucaena* as living support for yams, winged beans and other crops (e.g., pepper, betel, vanilla, and passion fruit).

FORAGE

The leguminous trees commonly used for forage, following continuous clipping, include *Cassia sturtii, Desmanthus virgatus, Leucaena leucocephala,* and *Sesbania grandiflora.* Foliage of other species is palatable to animals and could be recovered during wood harvest, e.g., *Acacia mearnsii, Albizia lebbek, Gliricidia sepium* and *Mimosa scabrella* (see Table 4). *Leucaena,* the most intensively studied of the species listed above, can produce 10-15 tons (dry matter) of forage per hectare annually (Brewbaker *et al.*, 1972) when harvested regularly. The value of the foliage as co-product in fuelwood or pulpwood harvest may be great enough in the case of *Leucaena* to encourage use of chip-vacuum, leaf-meal recovery machines.

Many of the 600 *Acacia* spp. bear phyllodes (expanded petioles) as mature leaves that are generally fibrous and unpalatable. Mimosine (in all *Leucaena* spp.) and other alkaloids occur in some tree legumes and require caution in their use as forage. Breeding and management of the forage (e.g., silage preparation) may offer solutions to these problems (González, Brewbaker & Hamill, 1968; Rosas, Quintero & Gómez, 1980).

UNIVERSITY OF HAWAII TRIAL NETWORK FOR N_2-FIXING TREES

The US National Academy of Science reports on *Leucaena* and on tropical legumes prompted an expansion of genetic research in Hawaii on N_2-fixing trees, previously confined to *Leucaena* and *Acacia koa.* A major thrust of the expanded studies is to determine relative biomass yields of different species and varieties of leguminous trees. A trial network for *Leucaena* was initiated in 1978, and expanded with USDA support in 1980 to include other species.

The major species chosen for our studies are summarized in Tables 3 and 4. All are considered relatively fast growing, with most species exceeding 15 m^3/ha per yr of wood. Most are hardwoods with high intrinsic value as fuel or pulpwood, and several are valued for forage or lumber and craftwood. Acid and unusually arid soils, along with waterlogged and saline soils, present primary challenges to the forester. In this study *Acacia auriculiformis* was chosen for relative tolerance to acidity and *Prosopis pallida* for relative tolerance to aridity.

Yield trials are planted with dense spacing (5000 or 10,000/ha) using 3- to 4-month-old seedlings transplanted into small plots (minimally 28 m^2). Trials use the augmented block design (Federer & Raghavarao, 1975), and include several replications of 10-15 species, but can include additional unreplicated plots of other species or treatments. This is a flexible design that accommodates diverse entries and treatments at different locations, yet permits the pooling of replicated data for calculations of variety x location and error terms.

Initial results of such international trials with *Leucacena* have been gratifying. Giant varieties of *Leucaena* provide some of the fastest growth and greatest versatility of the tree legumes, probably equal to any nonlegume.

RESEARCH IMPERATIVES

With perhaps a thousand potentially significant N_2-fixing trees to study in the tropics, where should research emphasis be placed? It seems wise to focus on species providing both forage and fuelwood to the small farmer. Few nonlegumes bear consideration, and species achieving less than 2 m annual growth should be excluded. Thorniness must be considered undesirable, despite the protection it gives against animal depradation. The following dual-purpose species appear to deserve extensive collection, genetic evaluation, and site adaptability studies:

Acacia spp. (see Table 2)
Calliandra calothyrsus
Gliricidia sepium
Leucaena leucocephala
Prosopis spp. (Table 2)
Sesbania grandiflora

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APPENDIX F

PRODUCTION OF FUELWOOD AND SMALL TIMBER IN COMMUNITY FORESTRY SYSTEMS[1]

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Abstract: Fuelwood and small timber plantings have the same attributes as other forestry plantations, but are generally characterized by short-rotations, more intensive management, higher population densities, and higher yields. Several specific management practices are discussed with regard to small farmer or community forestry production systems. Fuelwood yield data from four sites in Hawaii are presented, suggesting yields of $>10 m^3$/ha/yr in one-year rotations are possible over a wide range of sites.

INTRODUCTION

Plantation production systems for fuelwood and small timber can be as diverse as the sites on which the trees are grown or as varied as the inputs used to produce these products. However, community fuelwood and small timber plantations are generally characterized by shorter rotations, more intensive management, and higher mean annual wood yields than traditional forestry plantations. Community forestry plantations are most often small-scale plantings, and may involve small, scattered plantings by individual farmers.

The shorter rotations and higher mean annual increments associated with community forestry plantations make the management problems of these plantings similar to those faced by agriculturists concerned with annual food crops. Often times these plantations are sited in areas with limited arable lands, or on sites which are marginally usable due to topographic, climatic or soil fertility problems. These land area and land quality constraints, coupled with the needs of local populations for fuelwood or small timber, often demand the maximumization of wood yields per unit of land area. This then requires the intensification of management. Establishment, maintainence and harvesting operations are performed more often in fuelwood and small timber plantings than in other forestry plantations, and thus require more intensive management of soil fertility and soil erosion risks than longer-rotation crops.

The general steps required for plantation management of forestry tree species are similar regardless of the rotation age, or management intensity. This paper will present several management aspects which are of particular importance to short-rotation fuelwood and small timber production in the tropics.

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[1] Paper presented at Regional Workshop on Community Forestry, FAO/East-West Center, August, 1983, Nakorn Rachasima, Thailand.

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WOOD YIELDS AND LAND AREA REQUIREMENTS

Planners, community leaders and those associated with the management of community forestry projects must have an idea of the land area required to meet local fuelwood and small timber needs before beginning production operations. In order to estimate these land area requirements, some estimate of wood yields must be made.

Wood yields are subject to tremendous variation due to a variety of environmental and biological conditions. For estimation of fuelwood requirements and production, additional variables such as specific gravity, moisture content and calorific values of the wood must be considered. The following wood volume yields have been derived from four experimental sites in different environments in the State of Hawaii (Table 1).

Table 1. Stem wood yields of selected nitrogen-fixing tree species at one year

	Location				
	Waimanalo[1]	Molokai	Waipio	Niulii	Mean
Species	m^3/ha/yr				
Leucaena leucocephala	49a*	68a	24b	4cd	33a
Leucaena diversifolia	36ab	42b	32a	14a	8c
Sesbania grandiflora	24bc	57b	20b	6bc	8c
Calliandra calothyrsus	12cd	12c	3c	8b	8c
Acacia auriculiformis	15cd	7c	2c	1d	6c
MEAN	27b	37a	16c	6d	22

1/ MAI from 1.5 year calculations

* Means followed by the same letter within each location are not significantly different at p=.05 level by Duncan's Multiple Range test.

While Table 1 shows tremendous variation in stem wood yields between species within sites, and between locations, at least one species yielded over 10 m^3/ha/yr at every site. The differences between species in these experiments demonstrates the need for careful consideration of site characteristics and species requirements. For example, improper species selection by a farmer at the Niulii site could result in a decrease in productivity of over 1,300%.

Estimates of the land area required by small farmers or community forestry projects for meeting fuelwood needs are difficult at best. Major projects should not be initiated without some empirical yield data. A general estimate of land area requirements can be drawn from experimental wood yields of very short-rotations of one year. For example, assuming a family's average annual fuelwood requirements to be 5 m^3/yr, the planting area required might be from 1000m^2 to 5000m^2 (Table 2). Plantings could be done in blocks or in rows along fences, hedges, bunds or other under-utilized areas.

The estimates provided for perimeter plantings in Table 2 are very conservative since actual wood yields in perimeter plantings are undoubtably higher per unit area than those for block plantings. Block plantings require less total land area than perimeter plantings, but allow very few intercropping options. Perimeter plantings require large total land area, but allow use of a greater proportion of that land area to be planted to other crops.

Table 2. Estimated land area required to supply fuelwood for an average family of five.

Annual wood yield (m^3/ha/yr)	Block planting		Perimeter planting	
	- ha -	- rai -	- ha -	- rai -
10	0.5	3.1	12.5	78
25	0.2	1.2	5.0	31
50	0.1	0.6	2.5	16

Land allocation to fuelwood production is a difficult problem in areas with severe land area limitations, yet one which must relate directly to the severity of fuelwood shortages. The difficulty in allocating suitable lands for fuelwood plantings requires the following general steps:

1. Community involvement in assessment of the need for fuelwood or small timber production to meet local needs. This involvement is crucial throughout the land allocation process and subsequent plantation establishment;

2. A preliminary estimate of the land area required to meet fuelwood requirements;

3. Identification of specific parcels of land which might meet the estimated land area requirements;

4. Careful estimation of potential productivity on the identified sites;

5. Final site selection by community members. This step requires access by local decision makers to the technical information produced in steps 2-4. This information must be presented in a manner which is clear and easily understood.

Once the issues associated with land allocation have been resolved, and a site selected, the process of plantation establishment and management can begin.

PLANTATION ESTABLISHMENT AND MANAGEMENT

The success of fuelwood and small timber plantations is largely dependent upon careful establishment and management in the early stages of growth. This is true of all types of forest plantations, but is of special importance in fuelwood plantations utilizing nitrogen-fixing tree species (NFT) and several other fast-growing species due to their slow initial growth and the intolerance of these species to shading. Thus the major portion of labor and material inputs to community forestry plantings should be during the initial 12-18 months during which crucial establishment and management operations must be carried out.

The selection of species and the preparation of planting materials are often the least expensive operations in plantation management, yet are two of the most important. Serious consideration must be given to matching the environmental requirements of the desired species to the planting environment. There are no "miracle trees" which grow well on all sites, yet there are generally tree species which are well adapted to all but the most extreme sites. The importance of species selection to productivity is demonstrated by the data presented in Table 1. Likewise, varieties or provenances of species such as Eucalyptus camaldulensis or Leucaena leucocephala might be selected for special environmental adaptations or product utilizations.

Once species and varietal selections have been made, seed source selections must be made. Seed may be obtained from commercial sources or may be produced locally. Forest tree seed may be ranked into 5 general preference classes (Seeber and Agpaoa, 1976):

Highest	Preference Rating	Specifications
	1	From genetically superior trees, proven by progeny tests in zones where trees will be planted;
	2	From genetically superior trees, proven by progeny tests outside the planting zone;
	3	Not progeny tested, but seed was collected from rigidly selected trees or stands from localities with similar climatic and geographic features;
	4	Not progeny tested, but from natural stands and successful plantations of known geographic origin;
	5	Neither source certified or selected.
Lowest		

Seed should be selected from the highest preference class possible. However, seed of most fast-growing tropical fuelwood species is only available from preference classes 3-5.

Seed preparation practices are important in the establishment of fuelwood plantations, particularly in areas with distinct wet and dry seasons or in direct-seeded plantations where early, uniform germination is essential. The most important practice required to prepare seed of many fast-growing species for planting is scarification, particularly for many NFT species. Scarification is the process used to weaken the seed coat of hard-cated seed to allow water to penetrate and hasten germination. A wide variety of scarification methods can be used, including:

1. Mechanical scarification--using carborundum, files, fingernail clippers, or commercial drum scarifiers;

2. Hot water treatments--soaking of seed in 80-100C water for short periods of time to soften the seed coat;

3. Chemical treatment--seed are soaked in sulphuric acid and rinsed thoroughly in water.

Scarification techniques vary with the quantity of seed to be prepared, the tools which are available, and the type of seed to be scarified. The general rule is to scarify seed so that the seed coat is weakened enough to allow water to enter, and at the same time take care to avoid damage to the cotyledon and embryo. Other techniques to hasten germination such as cold water soaking, or alternate soaking and drying may be necessary for some species (Seeber and Agpoa, 1976).

Plantations may be established from seedlings, stem cuttings, or direct seeding. Each of these types of plantings must be done during periods of adequate rainfall, and must be protected from weeds and pests. Seedlings of a number of fast-growing fuelwood or small timber species are slow starting, do not tolerate severe weed competition, and must be planted into well-prepared seedbeds to obtain the most rapid early growth.

Weed control is the most important maintenance operation with fast-growing fuelwood and small timber plantation species. The number of weedings which must be done may vary tremendously with site qualities, quality of planting materials and previous uses of the planting site. Generally, the more hot and humid the site, the smaller and poorer the quality of the planting stock, and the wider the spacing of the seedlings, the greater the number of weedings which must be done. Thorough site preparation, good quality planting materials, and high population densities are all means of reducing understory weed competition. The greatest biomass productivity for a variety of species in short rotations have also been at high population densities (e.g. 10-40,000 trees per hectare), planted into well-prepared seedbeds (Henry, 1979; Van Den Belt, 1983).

In the case of nitrogen-fixing tree species, nitrogen-fixation is done by soil-borne bacteria in symbiosis with the tree. For this fixation of atmospheric nitrogen to take place, it is essential that these bacteria be present in the soil. If the selected species have not been grown in the planting area, inoculum containing these bacteria may need to be imported and mixed with seed prior to planting. Agricultural departments should be able to suggest available sources of inoculum.

Fertilization is a practice used to increase production on millions of hectares of forest land every year (Ballard, 1979). Although escalating fertilizer costs may severely limit fertilizer use in community forestry projects, soil amelioration may be an important consideration when considering marginal lands, which may be the only lands available for local fuelwood or small timber production. Without some fertilization or amelioration many of these lands would be likely be very unproductive, with high failure rates, and disappointing end results. A single such failure in a community development project may mean a serious loss of confidence in the sponsoring agency and make future development efforts far more difficult.

Simple experimental or observational plots with several rates of fertilizer or lime applied could prevent such failures and provide a very cost-efficient means of insuring future success. Although numerous problems exist in the diagnosis of fertilizer needs and optimum fertilization rates, it is clear that there are often significant responses to fertilizer at levels far below the optimum fertilization levels which may allow the use of otherwise unsuitable sites (Hu, 1981; Weidelt, 1976). The use of nitrogen-fixing species such as Leucaena leucocephala may virtually eliminate the need for nitrogen fertilizers, although the growth of leucaena and other NFT species may be limited in many parts of the tropics by phosphate or calcium limitations (Brewbaker and Hutton, 1980; Hutton, 1983).

Roguing, or the removal of off-type trees is an important maintenance operation when plantings are to be used for seed collections.

SUSTAINABLE PLANTATION MANAGEMENT

Fuelwood plantations used in small farmer or community forestry systems in the tropics are generally characterized by short rotations of less than 5 years. Cultivation of such plantations is often more intensive and nearly always less extensive than other types of forest plantations. Fast-growing tree species used in such plantations serve as nutrient pumps which remove nutrients from the soil and cycle them through the mechanisms of litterfall, rainwash from leaves, windthrow and decay of stems, branches and roots. This cycling process is interrupted by the harvest of a plantation just as it is by the harvest of agricultural crops.

In order to sustain production on a single site, the negative effects of harvesting must be minimized. This can be done by attending to:

1. Fertility management. Care must be taken to either retain as many of the nutrients taken up by trees on the site as possible, or to replace nutrients which are removed. Nutrient losses might be minimized by allowing harvested trees to dry on the site before removal to allow leaves to dry, fall off and remain on the site. Nitrogen-fixing plants might be used to improve and maintain soil productivity (Brewbaker, MacDicken and VanDenBelt, 1981; Haines and DeBell, 1979). Where the whole tree is of use off-site, an alternative would be to replace the nutrients removed with the tree by applying fertilizers, animal manures or green manures.

2. Erosion control. Removal of the forest canopy can result in increased danger of erosion, and the further loss of plant nutrients. Soil erosion losses must be minimized by minimizing the risk of exposing soils to the erosive forces of rainfall and runoff. Harvests should be scheduled for periods of little or no rainfall to reduce the risk of exposing bare soil to highly erosive rains. However, this may become risky when regeneration by coppice regrowth is anticipated. A possible solution would be to harvest during periods of light rainfall

where adequate moisture is available to support coppicing.

All farming operations run the risks of soil fertility depletion and soil erosion. Short rotation plantations of fast-growing trees are no different. While many soil conservation measures such as contour ditching may be beyond the financial capacity of most farmers or community forestry projects to implement, the proper selection of site and attention to vegetatively covering the soil during periods of heavy rainfall are low-cost means of will greatly reducing the erosion hazard (El-Swaify, Dangler and Armstrong, 1982).

CONCLUSION

Community forestry production of fuelwood and small timber requires particular attention to thoughtful assessment of the land area required to meet community fuelwood or small timber needs, careful selection of species, and intensive management of young stands. Plantation management in short-rotation systems also neccesitates consideration of means to sustain productivity over time with a minimum of external inputs.

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APPENDIX G

Leucaena as a fallow improvement crop: A first approximation[1]

Kenneth G. MacDicken

Abstract

Relevant literature regarding leucaena as a fallow improvement crop is reviewed and a comparison made between potential nutrient contributions of leucaena and actual nutrient contributions under other tropical secondary forest fallows. A description of a leucaena-based fallow system used in the Philippines is also presented.

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[1] Paper presented at Workshop on Environmentally-Sustainable Agroforestry and Fuelwood Production with Fast-Growing, Nitrogen-Fixing, Multi-Purpose Legumes, November 12-20, 1981, East-West Center, Honolulu, Hawaii.

Introduction

Numerous attempts have been made to solve the problems of site degradation due to shifting cultivation by focusing attention on improvement of the fallow period (Sanchez 1976). Indeed, that period wherein the physical and chemical properties of the soil are restored to a site has been called the key to the long-term success of shifting cultivation (Ewel 1976).

Accumulation of nutrients and organic matter under various types of both mature tropical forest vegetation and fallow crops has been described (Greenland and Kowal 1960; Nye 1961; Jaiyebo and Moore 1964; Juo and Lal 1977). Such studies show that both the type and age of a fallow crop may greatly influence the fertility status of a site by the end of the fallow period.

In recent years the leguminous tree Leucaena leucocephala (leucaena) has shown promise as an effective fallow improvement crop (Parfitt 1976; IITA 1980). However, there remains a lack of information on the effects of a leucaena fallow in shifting cultivation systems on such parameters as soil erosion and soil nutrient contributions.

This paper is presented in two sections. Section I presents a brief review of the literature dealing with fallow improvement in general and more specifically with leucaena as a fallow improvement crop. Section II outlines a fallow improvement system utilizing leucaena which was developed in the Philippines.

Section I Fallow Crop Improvement

The importance of accumulation of organic matter and nutrients during the fallow period under native vegetation has been studied and verified throughout the world (Greenland and Kowal 1960; Nye and Greenland 1960; Zinke, Sabhasri and Kunstadter 1970; Ewel 1971). A number of other studies have examined the changes in the soils chemical and physical properties under both arboreal and herbaceous fallow crops (Jaiyebo and Moore 1964; Parfitt 1976; Juo and Lal 1977).

A number of attempts have been made to improve the efficiency of the fallow period by speeding up the nutrient accumulation process through the use of fast-growing species (Nye and Greenland 1960; Sanchez 1976).

Jaiyebo and Moore (1964) found marked accumulation of exchangeable cations, nitrogen and organic matter under both planted herbaceous fallows and natural bush fallow. Little relationship between soil and plant Ca and Mg was found, but both the percentage and yield of N in the plants related closely to total N levels in the soil.

Corn crop yields following these fallow crops were statistically the same as those following the bush fallow or tropical kudzu, but were markedly lower when proceeded by the grass fallow. A high correlation ($r = .87$) was found between soil organic matter content and corn yields.

Juo and Lal (1977) also found an important relationship between soil organic matter content and productivity. They estimated that in order to prevent deterioration of chemical, physical and biological properties of the forest soil through maintenance of humified and partially decomposed organic matter, some 10-20 MT/ha/yr of dry matter would be required as a surface mulch.

It can be said then that in order to be effective, a fallow improvement crop should yield higher levels of N and accumulate more organic matter than the natural fallow it is to replace. In addition, the planted fallow must not produce effects which are deleterious to future plant growth or which enhance soil erosion.

Additional criteria for selection of species for use in community based agroforestry systems have been suggested by a number of writers (Weaver 1979; FAO 1977). Most important of these are:

1. The capacity to produce foodstuffs and wood throughout the year.
2. The ability to contribute to soil and water conservation.
3. Low soil fertility requirements and are yet fast-growing.
4. Co-products which are easily stored.
5. The ability to contribute to soil fertility improvement.

Leucaena is one of many species which appear to meet these requirements. Although extensive research is being conducted on leucaena in Hawaii and throughout the tropics, the long-term suitability of the species as a fallow improvement crop remains untested. However, the prognosis appears good; thus far the only major problems reported have been in areas where leucaena has been planted on sites to which it is not suited, or where it has been poorly managed.

Leucaena As A Fallow Improvement Crop

In determining whether or not leucaena as a fallow crop results in significant improvement of soil chemical and physical properties, several questions must be addressed.

1. Does leucaena contribute significantly greater amounts of nutrients to the upper horizons of the soil than does secondary forest regrowth?
2. Do these nutrient additions contribute to significant increases in subsequent crop growth?
3. Are nutrient losses from a leucaena-based fallow system likely to be greater than those from a secondary forest regrowth fallow?

Nutrient additions to the soil

Several nutrient pathways have been identified in tropical forest nutrient cycles (Jenny et al 1949; Nye 1961) which must be assumed to be of the same relative importance under stands of leucaena. These pathways are:

1. Litter fall
2. Timber fall
3. Root decomposition and nutrient excretion from roots and root nodules
4. Rain wash

Litter fall has been found to be the single most important pathway of nutrient transfer in tropical forests (Jenny 1949; Nye 1961; Golley 1975), and may be assumed to be the most important pathway under a leucaena fallow crop as well. The addition of large quantities of nutrients following the harvest of leucaena at the end of the fallow period is most likely of the greatest importance to the succeeding annual crop. For the purpose of this paper, only additions from litter fall and foliage left as a mulch at harvest will be discussed.

Although only limited data are available, litter fall rates under two-year old leucaena stands in the Philippines are reported to be nearly 13 T/ha/yr compared with less than 9 T/ha/yr for secondary forest stands (UHP 1980). These rates compare favorably with the litter fall rates of 7-15 T/ha/yr reported elsewhere for tropical secondary forests (Laudelot and Meyer 1954; Nye 1961; Golley 1975; Ewel 1976).

The elemental composition of both fresh leaf tissue and senescent leaf tissue is generally higher for leucaena than for the mixed tropical forest vegetation analyzed by Nye (1961), Greenland & Kowal (1964) and Ewel (1976) (Table 1).

Table 1. Mineral nutrient content of leucaena leaf tissue and mixed forest vegetation

Site & type of vegetation		elemental composition (%)					Source
		N	P	K	Ca	Mg	
Hawaii	leucaena (fresh leaves)[1]	2.90	.15	2.75	2.22	.40	MacDicken unpublished data 1981
	leucaena (litter)[1]	1.91	.11	2.01	2.55	.38	
Guatemala	1-yr old mixed forest (fresh litter)	1.61	.07	.23	1.54	.87	Ewel 1976
Ghana	Mixed deciduous (14 spp).						Nye 1958 quoted in Greenland & Kowal 1960
	leaf tissue	2.52	.14	.85	1.54	.48	
	litter	1.29	.05	.44	1.59	.31	

1) Based on a limited sample size.

Leucaena litter was found to contain higher quantities of each of the major nutrients than those values reported for mixed forest fallows in Guatemala and Ghana.

The estimated differences in the potential nutrient contribution of the litter to soil fertility between leucaena and natural secondary forest fallows are shown in Table 2.

Table 2. Estimated nutrient return via litter fall under mixed forest and leucaena stands

Type of Vegetation	Age of Vegetation	Dry Weight (T/ha/yr)	Mineral Nutrients (Kg/ha/yr)					Source
			N	P	K	Ca	Mg	
Leucaena	1 Yr.	12.91[1]	247	14	259	329	49	UHP 1980, MacDicken
Mixed forest (Guatemala)	1 Yr.	4.6	74	3	11	71	40	Ewel 1976
Mixed forest (Ghana)	40 Yrs.	10.5	199	7	68	206	45	Nye 1961

1) Based on litter fall observed in the Philippines (UHP 1980)

It should be emphasized that the estimates presented for leucaena are preliminary in nature, and are based on a very limited sample size.

As shown in Table 2, the total amount of nutrients assumed transferred to the soil surface under leucaena is generally much greater than that reported under mixed forest fallows. However, what is not known is what happens to these nutrients after they are deposited on the soil surface.

Parfitt (1976) and Juo and Lal (1977) have reported several changes in soil chemical and physical properties under leucaena fallows.

In studies done in Papua New Guinea, Parfitt (1976) reported an increase in soil nitrogen from .23% to .75% after two years of a leucaena fallow following one year of *Ipomea batatas* (Table 3).

Table 3. Soil nitrogen status changes under sweet potatoes and leucaena in Papua New Guinea

Site	Crop	Cropping Period	%N
Sialum	*Imperata cylindrica*		.35
	Ipomea batatas	1 yr.	.23
	Leucaena leucocephala	2 yrs.	.75

SOURCE: Parfitt, 1976

It was further reported that undergrowth was virtually nonexistent at the end of the two-year leucaena fallow, presumably due to the shading effects under closed canopies.

Juo and Lal (1977) studied the effects of a leucaena fallow upon selected soil chemical properties on an Alfisol in Western Nigeria (Table 4).

Table 4. Exchangeable cations, CEC, Total N and pH of surface soil (0-15 cm) after 3 years under bush regrowth and leucaena fallow.

			Exchangeable cations (meg/100g)			Total
	pH (H_2O)	Effective CEC (meq/100g)	Ca	Mg	K	N %
Bush regrowth	6.5^a	4.94^a	3.34^a	.89^a	.42^a	.130^a
Leucaena	6.4^a	6.22^b	4.12^b	1.14^a	.73^b	.146^a
LSD (.05)	.36	1.03	.77	.31	.21	1.032

Source: Juo and Lal, 1977

The leucaena fallow was found to have resulted in significantly higher effective CEC, exchangeable Ca and K levels than did the bush fallow. In this experiment, leucaena foliage was cut annually and left as a mulch. The lack of significant improvement in total N suggests that much of the nitrogen in the leucaena leaf tissues is lost through volatilization, carried off in runoff and/or eroded sediments or is leached out of the surface horizons.

The significant difference in exchangeable calcium between soils under leucaena fallow and soils under bush fallow suggests that perhaps leucaena with its tap root system is more effective in bringing up cations leached from surface horizons than is the bush fallow. If this recycling of bases is indeed the case, then such a fallow may be a practical alternative to liming acid soils (Greenland 1975).

Thus far, the discussion has focused on nutrient contributions during the fallow period. In shifting cultivation however, the greatest contribution in terms of available nutrients takes place just prior to planting (Nye and Greenland 1964; Sanchez 1976).

Often times this flush in the release of nutrients is due to the burning of felled vegetation. The system discussed here (Sec. II) does not require burning prior to the planting of annual crops. This is due to the fact that virtually all of the undergrowth vegetation is shaded out by the time the site is cleared in preparation for planting, and the remaining leucaena stems are easily removed from the area to be planted. Burning may be desireable as a management tool in this system, as it is in a wide variety of other shifting systems, for a number of reasons such as improved seedbed preparation, more rapid release of nutrients, liming effects of the ash and others (Ruthenburg 1980; Rambo 1981).

However, if fire were used in systems such as that described in Sec. II with trees which coppice as vigorously as leucaena, much of the advantage of coppice regrowth would be lost due to mortality caused by fire. Nutrient losses of nitrogen and sulphur due to volatilization during burning would also reduce the amounts of those nutrients available following fire (Sanchez 1976).

Assuming that clearing is done during the dry season and that burning is not required and much of the wood produced during a leucaena fallow is removed from the site after clearing and drying, the release of nutrients from the remaining dry matter (leaves, litter, twigs and branches) would likely begin at the onset on the rainy season. This of course, coincides with the planting schedule generally utilized by shifting cultivators, thus providing nutrients for the newly seeded crop.

Preliminary data from studies at the University of Hawaii indicate that up to 3.6 T/ha of dry leaf material are present in the canopies of one-year-old leucaena (Van Den Beldt, unpublished data). This provides a rough conservative estimate of the amount of material which can be expected to be left on the soil surface following clearing.

Total nutrient contribution to the soil surface at clearing, assuming the same approximate nutrient content as that shown above (Table 1), is shown in Table 5.

Table 5. Total estimated nutrients transferred to the soil surface at clearing after a leucaena fallow.

Vegetation type	Estimated dry matter	Nutrient Addition (Kg/ha)				
	(Kg/ha)[1]	N	P	K	Ca	Mg
Leucaena (1 yr old)	3,570[2]	104	5.4	98.2	79	14.3
Mixed Secondary forest (18 yr old)[3]	6,502	143	7.8	80.6	76.7	

1) Leaves only
2) Source: Van Den Beldt, personal communication
3) Source: Bartholomew 1953, Belgian Congo

With the exception of nitrogen, nutrient contributions to the soil surface at clearing of an 18-year old secondary forest fallow are very close to those estimated to occur following clearing of a one-year old leucaena fallow.

Litter fall data from under secondary forest regrowth suggests that the quantity of leaf material produced significantly increases over time (Ewel 1976). Preliminary studies with leucaena indicate that leaf dry matter in the canopy also increases with age, at least during the first year (Van Den Beldt, unpublished data).

Thus, nutrient additions from the harvest of a leucaena fallow of three-four years in age would likely be greater than those presented above in Table 5 for a one-year-old stand.

How these incremental improvements in soil fertility affect subsequent crop yields is as of now an unanswered question. Work done with leucaena as a component of sedentary farming systems suggests that leucaena as a green manure or intercrop does contribute to improved crop yields (Guevarra 1976; IITA 1979).

Studies done at IITA (1980) on maize yields following application of five tons of leucaena foliage per hectare as a mulch showed a 14% yield increase over the control. This suggests that application of leucaena leaves as a mulch should improve annual crop yields. However, as of yet, no comparison has been made to compare crop yields after a leucaena fallow with secondary forest regrowth fallows.

Despite this, the improvements shown in Total N, CEC, Ca and K (Table 5) suggest that leucaena does contribute to restoration of soil fertility at a faster rate than secondary forest fallows, and that this improvement probably leads to increased yields in subsequent crops.

Again, no data is available from which to estimate actual transfer of nutrients from the vegetation to the soil. Certainly, factors such as runoff losses, losses of eroded sediments, volatilization of N and S and leaching of nutrients will occur. However, it seems unlikely that nutrient losses under leucaena would be greater in proportion than those from under secondary forest regrowth.

Then if this assumption is indeed valid, fertility restoration can be assumed to be greater and more rapid under leucaena than under bush regrowth.

An additional factor which enhances the attractiveness of leucaena as a fallow crop is the relative ease with which it is managed. Secondary forest regrowth fallows are by their nature diverse in composition and spatial arrangement, making management difficult at best. Leucaena may be managed in a number of ways depending on the type of end product(s) desired.

An example of the benefits of such management is the thinning of a leucaena fallow at approximately two years (Section II). Such thinning not only produces fuelwood, but opens the canopy to prevent complete loss of ground cover through shading. The maintenance of vegetative cover reduces erosion (Wischmeier 1975, Dissmeyer 1981) and nutrient losses (Lal 1976, Vitousek et al. 1979). Indeed, a key element in any such fallow system must be management of the overstory in such a way that groundcover is maintained up until it is time for clearing and the erosion hazard is at a minimum.

Potential disadvantages

Although the opportunity for management is generally seen as an advantage, there also exists an inherent opportunity for mismanagement.

The most obvious consequences of such mismanagement would be complete shading of understory vegetation, thus increasing the erosion potential.

Another potential problem is a possible increase in pests and diseases in a monoculture of leucaena. Although this potential exists in most monocultures, monocultures of common leucaena have existed for many years without reported incidence of major pest problems.

Research needs

Before the use of leucaena fallow systems can be widely advocated a number of crucial questions must be addressed. These include:

- Do leucaena fallows cycle nutrients as efficiently as native secondary forest regrowth?
- Do the greater quantities of nutrients in leucaena litter significantly improve soil fertility and subsequent crop yields over and above the improvements made during secondary forest fallows?

Conclusions

In summary, the expected advantages of a leucaena fallow over secondary bush regrowth fallows are estimated to include:

1. Increased litter production with more rapid buildup of organic matter;
2. Higher nutrient content of deposited litter which may result in more rapid buildup of nutrients in the soil;
3. Greater ease of management;
4. Greater potential for marketing of co-products (e.g. leaf meal, fuelwood, etc.).

Potential disadvantages of leucaena fallow include:

1. Increased potential for pest damage to fallow crop;
2. Increased potential for environmental degradation due to mismanagement (e.g., increased sheet erosion due to complete shading out of ground cover).

Section II A description of a leucaena-based fallow system used on the island of Mindoro, Philippines

The fallow system outlined herein was developed for use on the island of Mindoro, Philippines. Its principle features are:

1. A cropping season - fallow crop rotation similar to that used in traditional shifting cultivation with leucaena as the fallow tree crop.
2. The rotation is based on a four-year cycle, with planting of leucaena stump cuttings taking place for only the first four years with one plot being cleared and planted per year. Annual crops are planted in the same field at the same time as the stump cuttings.

The system is outlined in Figure 1.

This system calls for the interplanting of leucaena stump cuttings into a mixed rice and corn cropping system. Stump cuttings are used for three reasons:

1. Stump cuttings are easily produced, transported, and planted by farmers with very little training.
2. Since the stumps have no foliage present at planting, and develop rather slowly for the first four-six

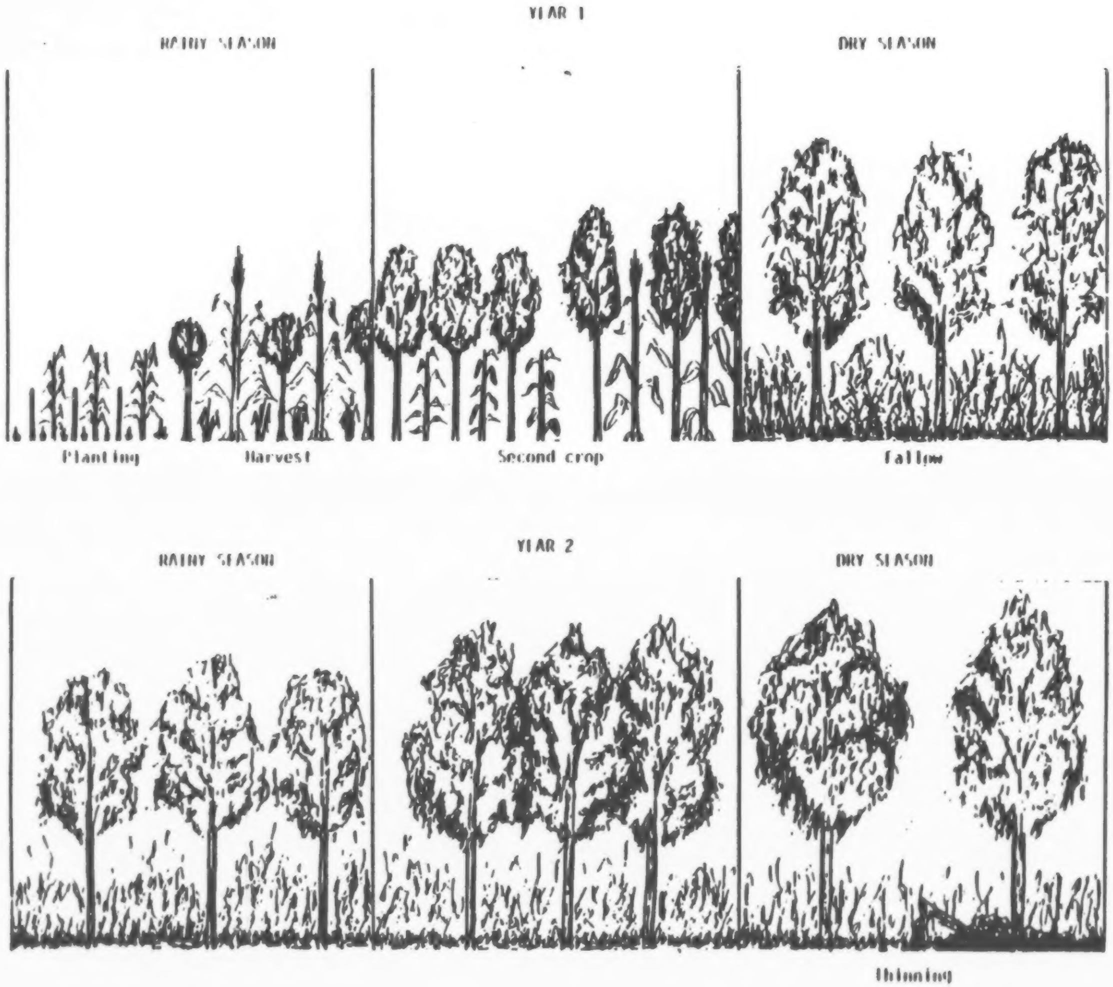
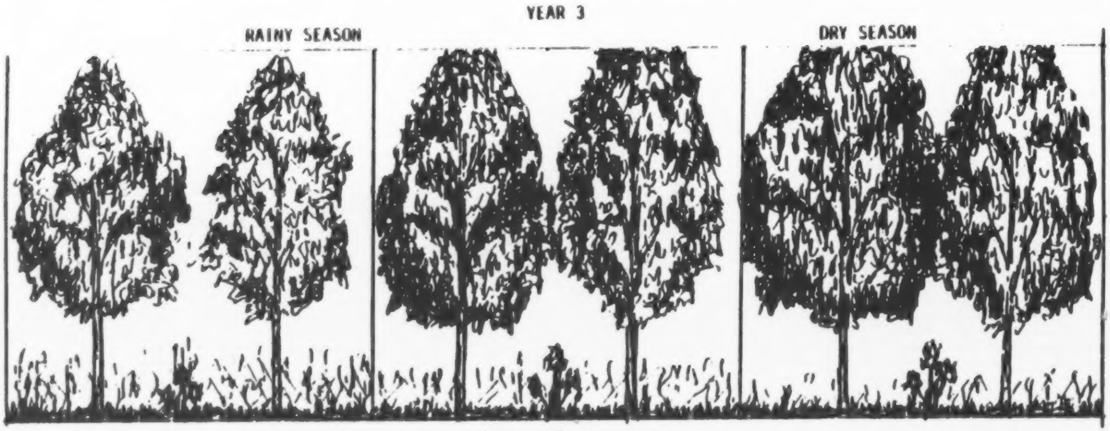
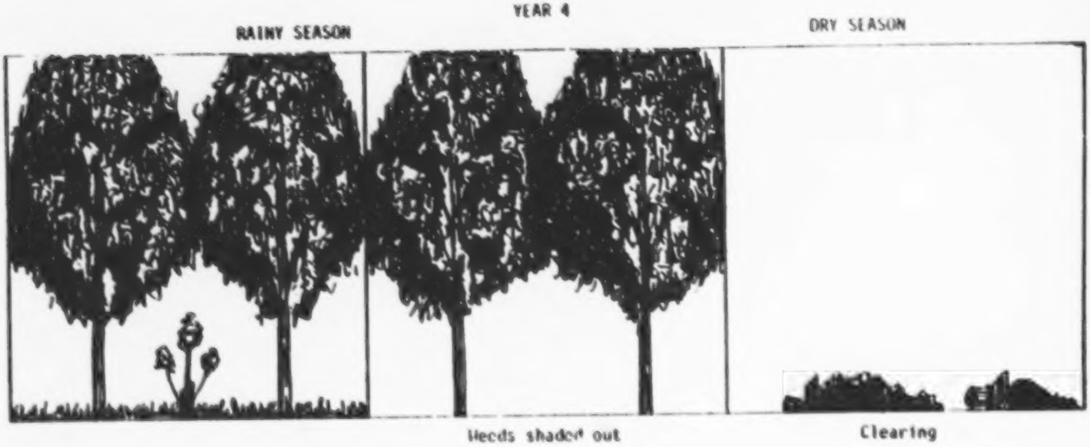
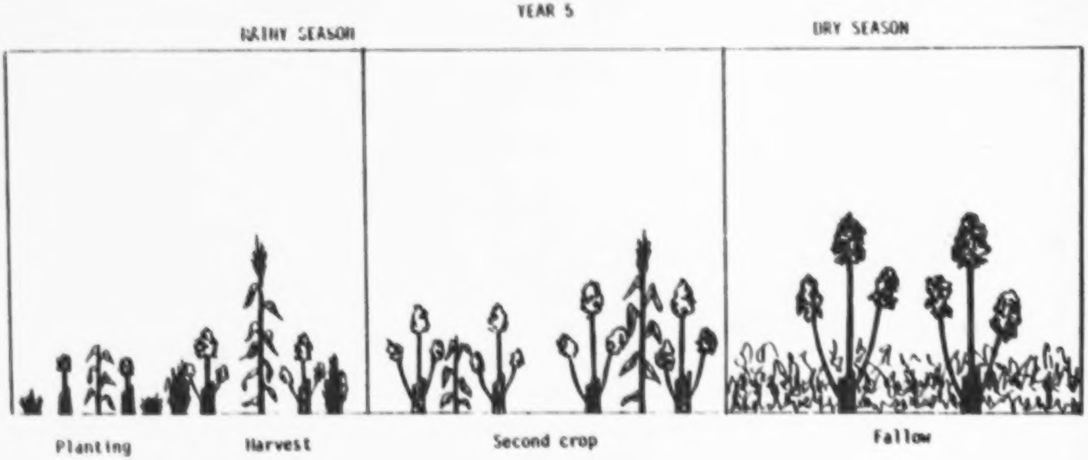

YEAR 1
RAINY SEASON
DRY SEASON
Planting
Harvest
Second crop
Fallow
YEAR 2
RAINY SEASON
DRY SEASON
Thinning

Figure 1. Cropping and management sequence utilizing leucaena as a fallow crop.


YEAR 3
RAINY SEASON
DRY SEASON

Canopy closes


YEAR 4
RAINY SEASON
DRY SEASON
Weeds shaded out
Clearing


YEAR 5
RAINY SEASON
DRY SEASON
Planting
Harvest
Second crop
Fallow

months, shading of the intercropped cereals is not a problem.

3. Stumps as long as 1m above the root cellar can be used, thus allowing very limited shading of the newly emergent leucaena foliage by the intercrop species.

This model was selected for the following reasons:

1. Simplicity - This system alters traditional practice in only three respects:
   a. Trees are planted along with the first crop of rice.
   b. Some management of the fallow is desirable (e.g. thinning).
   c. A rotation of ≤ five years is established between fallow plots.

   Thus, farmers can utilize the planting systems and crop species of their choice with little alteration, and little additional input of labor or capital.

2. Reduction in the amount of land needed:
   The shortened fallow period allows farmers to return to a previously farmed site much sooner than with natural secondary forest fallows, thus decreasing the number of sites needed to sustain production.

3. Potential for co-product utilization:
   With species such as leucaena a variety of co-products can be utilized (e.g. firewood, forage, etc.). The

community in which this system was developed has marketed leucaena leaf meal during the dry season, and utilized woody stems as firewood, thus increasing their cash income and reducing the amount of labor spent on fuelwood gathering.

4. Distribution of income generating activities throughout the year. In cases where co-product markets are available or on-farm utilization is possible, off-season production is feasible (e.g. leaf meal production during the dry season), thus distributing income over a greater portion of the year.

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APPENDIX H

NITROGEN FIXING TREES: GENERAL INFORMATION

1. DEFINITION OF NITROGEN FIXING TREES (NFT)

NFT species may be defined as all woody species known to fix nitrogen, are perennial and over 3m in height. Also generally included in this definition are: 1) all woody species of the legume family even though confirmation that they individually nodulate and fix nitrogen may be lacking; 2) all species of other genera in which a species has been confirmed to nodulate or fix nitrogen (NFTA, 1983).

2. TAXONOMY

Species of the legume family (Leguminosae) include the vast majority of nitrogen fixing trees. Most of these species are of the subfamilies Mimosoideae and Caesalpinoideae, and relatively few of the Papilionoideae. A high proportion of the tested mimosoids (98%) fix N, compared with the papilionoids (60%) and caesalpinoids (30%) (Brewbaker et. al., 1981). Nitrogen fixation has been measured in a number of other plant families including the genera Alnus, Myrica, Hippophae, and Casuarina (Bond, 1967).

3. GENERAL CHARACTERISTICS

NFT species often have multiple uses ranging from fuelwood, timber and pulpwood to green manure, animal fodder and food for human consumption. The foliage, flowers or seed pods of NFT are often usable as protein or nitrogen sources for other plants or animals, since they are often higher in nitrogen content than other non-nitrogen fixing plants in similar growing conditions. The generally higher foliar N content of many NFT species, as well as transfer of N from root nodules and rainwash often results in improvement of soil nitrogen content. NFT are often aggressive, pioneer species which are able to grow more rapidly without N fertilizer inputs than non-nitrogen fixing species.

4. IMPORTANT NFT GENERA

Over a thousand species are considered to be nitrogen fixing trees, many of which little is known. Among the most important genera are:

Acacia
Albizia
Alnus
Calliandra
Cassia
Casuarina
Ceanothus
Dalbergia
Enterolobium
Erythrina
Gleditsia
Gliricidia
Inga
Intsia
Leucaena
Mimosa
Myrica
Parkia
Pithecellobium
Prosopis
Pterocarpus
Robinia
Samanea
Sesbania

A listing of the most economically important species is attached.

APPENDIX I

ESTABLISHMENT AND MANAGEMENT OF NFT PLANTATIONS

1. INTRODUCTION

The success of NFT plantings is largely dependent upon careful establishment and management in the early stages of growth in both experimental and field plantings. This is true of all types of forest plantations, but is of special importance in NFT plantation establishment due to the slow initial growth of many NFT species, and the intolerance of these species to shading.

2. PREPARATION OF PLANTING MATERIALS

Although preparation of planting materials is often one of the least expensive operations in plantation management, it is one of the most important.

A. Species selection. Serious consideration must be given to matching the environmental requirements of desired species to the planting environment. There are no "miracle trees" which grow well on all sites, yet there are generally tree species which are well adapted to all but the most extreme sites.

B. Selection of seed sources. Seed may be obtained from commercial sources or may be collected or produced locally. Forest tree seed may be rated into the following classes:

Highest	Preference Rating	Specifications
|	1	From genetically superior trees, proven by progeny tests in zones where trees will be planted;
|	2	From genetically superior trees, proven by progeny tests outside the planting zone;
|	3	Not progeny tested, but seed was collected from rigidly selected trees or stands from localities with similar climatic or geographic features;
|	4	Not progeny tested, but from natural stands and successful plantations of known geographic origin;
|	5	Neither source certified or selected.
Lowest		

Seed of most NFT species is available only from preference classes 3-5.

B. Seed preparation. The most important practice required to prepare seeds of many NFT species for planting is **scarification.** Scarification is the process used to weaken the seed coat of hard-coated seed to allow water to penetrate and hasten germination. A wide variety of scarification methods can be used, including:

1. Mechanical scarification--using nail clippers, carborundum, or commercial drum scarifiers;

2. Hot water treatment--soaking of seed in 80-100C water for short (5 min.) periods of time to soften the seed coat;

3. Chemical treatment--seed are soaked in sulphuric acid and rinsed thoroughly in water.

Scarification techniques vary with the quantity of seed to be prepared, the tools which are available, and the type of seed to be scarified. The general rule is to scarify seed so that the seed coat is weakened enough to allow water to enter, and at the same time take care to avoid damage to the cotyledon and embryo.

3. PLANTATION ESTABLISHMENT

Plantings may be established from seedlings, stem cuttings, stump cuttings, or direct seeding. Each of these types of planting must be done during periods of adequate rainfall, and must be protected from weeds and pests. Seedlings of NFT species are often slow starting, do not tolerate severe weed competition, and must be planted into well-prepared seedbeds to obtain the most rapid early growth.

Since NFT fix nitrogen in cooperation with soil-borne bacteria, it is essential that these bacteria be present in the soil for nitrogen fixation to take place. If the selected species have not been grown in the planting area, inocula containing these bacteria may need to be imported and mixed with seed prior to planting.

Since phosphorous is the most common limiting macronutrient for NFT species, fertilization with superphosphate or rock phosphate is often necessary for optimum yields. In more acid soils (e.g. less than 5.0), calcium deficiency may be a major limiting factor which can be remedied by additions of dolomite or calcium sulphate.

4. MAINTENANCE

Weed control is the most important maintenance operation. The number of weedings which must be done may vary tremendously with site qualities, quality of planting materials and previous uses of the planting site. Generally, the more hot and humid the site, and the smaller and poorer the quality of the planting stock, the greater the number of weedings which must be done.

Roguing, or removal of off-type trees is an important maintenance operation when plantings are to be used for seed collections.

APPENDIX J

EVALUATION

Country____________________

1. Please rate the following sessions of the workshop;

	Very Poor	Fair	Ave	Good	Excellent
	1	2	3	4	5
Expectations					
Comments____					
____					
____					
Counterparts/WID	1	2	3	4	5
Comments____					
____					
____					
Concepts of Agroforestry (Vergara)	1	2	3	4	5
Comments____					
____					
____					
Ecology	1	2	3	4	5
Comments____					
____					
____					
Land Use Planning	1	2	3	4	5
Comments____					
____					
____					

Very Poor   Fair   Ave   Good   Excellent

Tuesdays' Field Trip

1   2   3   4   5

Comments____

____

____

Ecological, Economic & Social Advantage of Agroforestry (Vergara)

1   2   3   4   5

Comments____

____

____

Nitrogen Fixing Trees Part I (MacDicken)

1   2   3   4   5

Comments____

____

____

Nitrogen Fixing Trees Part II (MacDicken)

1   2   3   4   5

Comments____

____

____

Very Poor Fair Ave Good Excellent

Agroforestry Project Planning (Vergara)

1 2 3 4 5

Comments ____

____

____

Crops in Agroforestry (Dupree)

1 2 3 4 5

Comments ____

____

____

Cattle Under Trees (Knight)

1 2 3 4 5

Comments ____

____

____

Agroforestry & fuelwood production (MacDicken)

1 2 3 4 5

Comments ____

____

____

Very Poor   Fair   Ave   Good   Excellent

Sustained Productin....in Agroforestry (Vergara)

1   2   3   4   5

Comments ____

____

____

Extension (Dupree, Fillion)

1   2   3   4   5

Comments ____

____

____

Economics of Agroforestry (Vergara)

1   2   3   4   5

Comments ____

____

____

Nursery Management

1   2   3   4   5

Comments ____

____

____

	Very Poor	Fair	Ave	Good	Excellent
Seed Collection					
	1	2	3	4	5

Comments____

____

____

Grafting					
	1	2	3	4	5

Comments____

____

____

Pruning					
	1	2	3	4	5

Comments____

____

____

Agroforestry project					
	1	2	3	4	5

Comments____

____

____

2. In length, the workshop was:

☐ too short

☐ just right

☐ too long

Comments____

____

____

3. The technical level of the workshop was:

☐ too simple

☐ just right

☐ too technical

Comments____

____

____

4. What session was most useful to you?

5. What session was least useful to you?

6. What other topics would you have liked in this workshop?

7. What advantages/disadvantages do you see in training Peace Corps Volunteers and Host Country Colleagues together?

8. Would you recommend that this type of workshop be done again in the future? Please explain.

9. Do you have recommendations of other sites for similar trainings in the future?

10. Do you feel that the workshop achieved its goal?

[ ] yes

[ ] no

[ ] don't know

Comments____

____

____

11. Other comments and suggestions for the improvement of future training programs.

APPENDIX K

	1	2	3	4	5
EXPECTATIONS	0	3%	14%	69%	14%
COUNTERPARTS/WID	-	6.5%	28%	56%	9.5%
CONCEPTS OF AGROFORESTRY	-	-	3%	35.5%	61.5%
ECOLOGY	3%	6%	34%	46%	9%
LAND USE PLANNING	-	7%	40%	46%	7%
FIELD TRIP	15%	3%	22%	39%	21%
ECOLOGICAL, ECONOMIC & SOCIAL ASPECTS OF AGROFORESTRY	-	4%	6%	43%	47%
NITROGEN FIXING TREES I	-	4%	-	48%	48%
NITROGEN FIXING TREES II	-	-	10%	48%	42%
AGROFORESTRY PROJECT PLANNING	-	1%	17%	57%	25%
CROPS IN AGROFORESTRY	-	5%	50%	36%	9%
CATTLE UNDER TREES	-	11%	33%	31%	25%
AGROFORESTRY AND FUELWOOD PRODUCTION	-	3%	8%	61%	28%
SUSTAINED PRODUCTION IN AGROFORESTRY	-	3%	3%	48.5%	45.5%
EXTENSION	3%	9%	31%	35%	22%

	1	2	3	4	5
ECONOMICS OF AGROFORESTRY	-	6%	26%	44%	24%
NURSERY MANAGEMENT	-	11%	25%	42%	22%
SEED COLLECTION	-	11%	35%	43%	11%
GRAFTING	-	-	16%	45%	39%
PRUNING	-	12%	31%	54%	3%
AGROFORESTRY PROJECTS	17%	-	24%	45%	14%

Since 1961 when the Peace Corps was created, more than 80,000 U.S. citizens have served as Volunteers in developing countries, living and working among the people of the Third World as colleagues and co-workers. Today 6000 PCVs are involved in programs designed to help strengthen local capacity to address such fundamental concerns as food production, water supply, energy development, nutrition and health education and reforestation.

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